Porosity, Permeability and Profitability: Integrating Geology, Reservoir Engineering and Commercial Factors for Evaluation of Unconventional Resource Opportunities*

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Abstract

The results presented herein are from a map-based, uncertainty-aware workflow that incorporates inputs for geoscience, engineering, and commercial factors in order to evaluate unconventional resource at all play maturities.
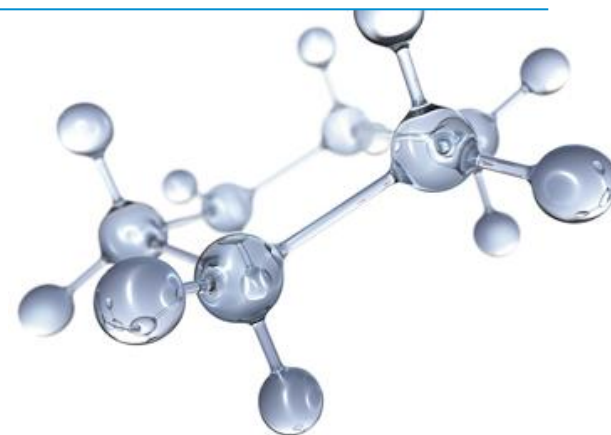
Conclusions are:

"Conventional" understanding of risk and uncertainty apply to unconventional resources, but unconventional resources challenge the definition of technically vs. commercially recoverable volumes.

It is critical to integrate geological, engineering, and commercial factors in the evaluation of unconventional resource opportunities.

Unconventional plays are continuously varying, and the spatial variation in the quality of the play must be accounted for in the evaluation of opportunity.

Porosity, Permeability and Profitability:
Integrating Geology, Reservoir Engineering and Commercial Factors for Evaluation of Unconventional Resource Opportunities

Kurt Steffen, PhD.

Outline

- What aspects are critical for evaluation of unconventional resources?

- How can geoscience, engineering, and commercial factors be integrated for evaluation of unconventional resources

- Demonstration of use on a synthetic dataset

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Critical aspects for evaluation of Unconventional Resources

- Spatial Awareness
  - A continuous resource is not the same everywhere
  - More accurately described as continuously varying resources

- Conventional evaluation concepts still apply, …..
  - Risk
    - Entire plays or regions of plays can fail (play or dependent risk)
    - Once a region of play has been proven, a proportion of wells may still fail (prospect risk, well risk, or future success ratio)
  - Uncertainty
    - Must be able to propagate uncertainty in geologic (net thickness, porosity, etc..), and engineering parameters (recovery factor)

- But unconventional resources highlight challenges to our conventional methods
  - Recovery factor is dependent on development spacing which is dependent on commercial considerations
  - Due to commercial considerations, there is often a large gap between **Technically Recoverable** and **Commercially Recoverably** Resources

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An Integrated Evaluation Workflow

- Inputs
  - Mapped-based risk inputs (play and well)
    - Includes dependency and correlations
  - Mapped-based inputs for geologic and reservoir engineering parameters
    - Defined as uncertainty distributions
  - Mapped-based development (well) plan
    - Lateral length, number of fracture stages
    - Well spacing handled as scenarios
    - Fracture size handled as uncertainty distributions

- Processing
  - Monte Carlo techniques are used to apply risk and generate trials that are simulated using ARM (Analytical Reservoir Model), an ExxonMobil internally developed reservoir modeling tool.
  - Run at different well spacing.

- Outputs
  - Rate/Time plots (flowstreams) for all Monte Carlo trials

- Commercial
  - Simplified (social) commercial factors (well cost, commodity price) are then used for commercial screening of plays using the Monte Carlo flowstreams at different commodity price assumptions
  - Project-based economics can be used to evaluate opportunities

Process

- Four steps
    - Traditional Volumetric-based play assessment
    - Incorporation of dynamic model (well-based economics)
    - Incorporation of projects
        - Type curves and spacing's tied back to geology
        - Spatial Awareness and variability within a project
    - Interaction of multiple projects with a play demand curve

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Inputs

	Scaler or Distribution	Mapped or Play Average	Distribution	Min Value	ML Value	Max Value
Risks						
Prospect Risk	Scaler	Mapped				
Play Risk and Dependency	Scaler	Mapped				
Already a Standard Assessment Input						
Net Thickness (ft)	Distribution	Mapped				
Porosity (fraction)	Distribution	Mapped				
Water Saturation (fraction)	Distribution	Non Mapped	Constant	0.4	0.4	0.4
Condensate Yield	Distribution	Mapped				
Gas Gravity (Air = 1)	Distribution	Non Mapped	Constant	0.85	0.85	0.85
Available Inputs						
Depth (ft)	Distribution	Mapped				
Pressure (PSI)	Distribution	Mapped				
Temperature (F)	Distribution	Mapped				
Permeability						
Vertical	Distribution	Mapped				
Horizontal	Distribution	Mapped				
Well Design						
Well Type (Horizontal or Vertical)	Scaler	Non Mapped	Horizontal			
Drainage Length (ft)	Scaler	Non Mapped	5280			
Drainage Width (ft)	Scenarios	Non Mapped	330 ft (40 Acre),495 ft (60 Acre),660 ft (80 Acre) ,990 ft (120 Acre),1280 Ft (160 Acre)			
Lateral Length (ft)	Scaler	Non Mapped	4800			
Number of Fractures (count)	Scaler	Non Mapped	12			
Fracture Half Length (ft)	Distribution	Non Mapped	Uniform	150	200	250
Fracture Height(ft)	Distribution	Non Mapped	Uniform	50	75	100
Surface Temperature (F)	Scaler	Non Mapped	70			
Well Radius (Ft)	Scaler	Non Mapped	0.33			
Roughness (Ft)	Scaler	Non Mapped	0.025			
Max Rate (kscfd)	Scaler	Non Mapped	40000			
Min Rate (kscfd)	Scaler	Non Mapped	30			
Well Life (Years)	Scaler	Non Mapped	40			
Min BHFP (PSI)	Scaler	Non Mapped	435			
Commercial						
Well Cost(MUSD)	Scaler	Non Mapped	5			
Discount Rate (%)	Scaler	Non Mapped	12%			
Gas Price (USD/KCF)	Scenarios	Non Mapped	1,2,3,4,6,8,10 $/KCF			

Input Maps
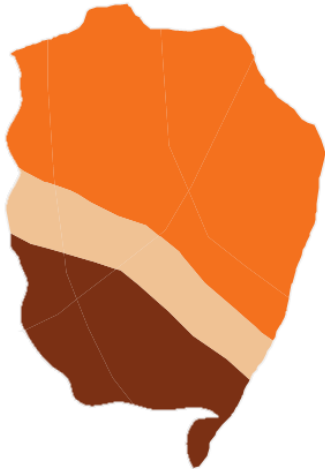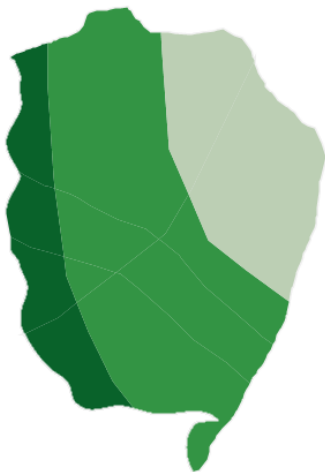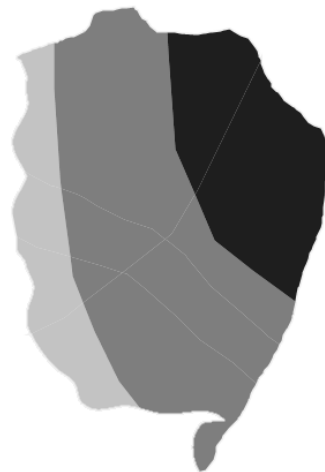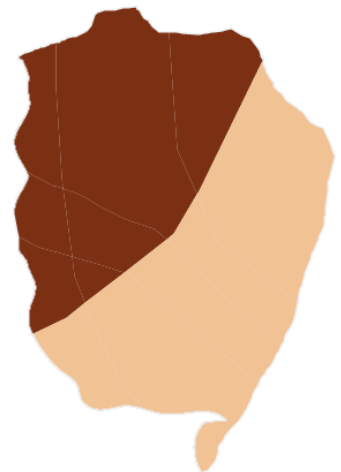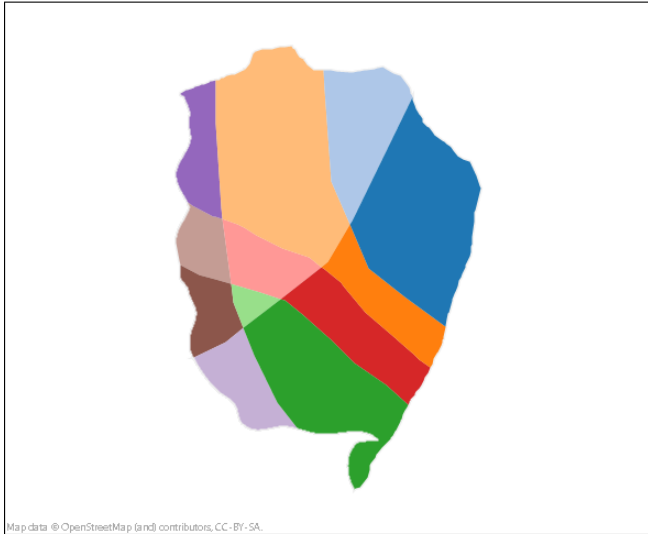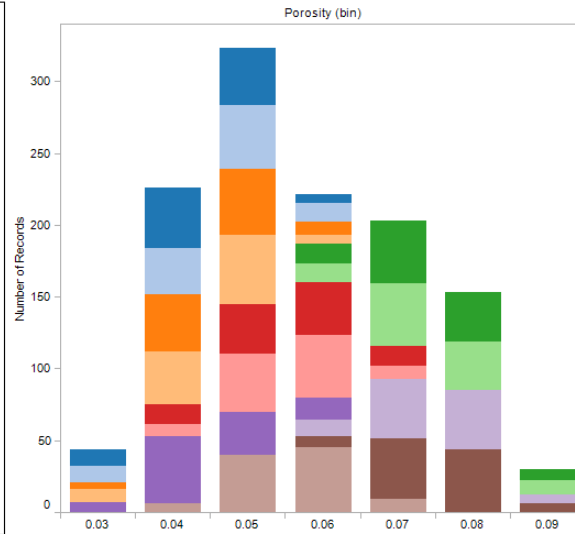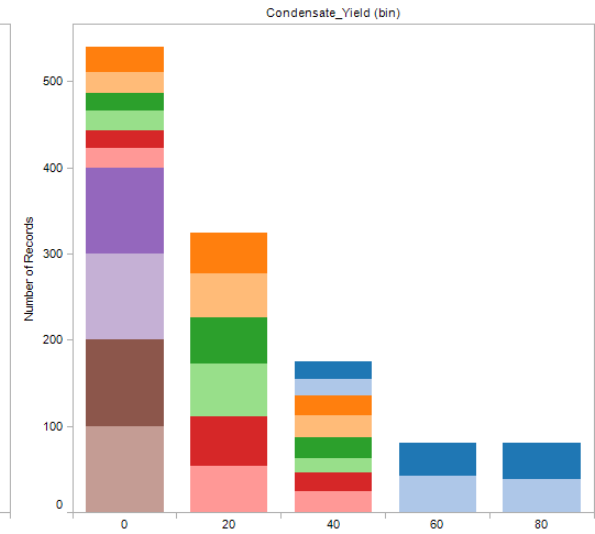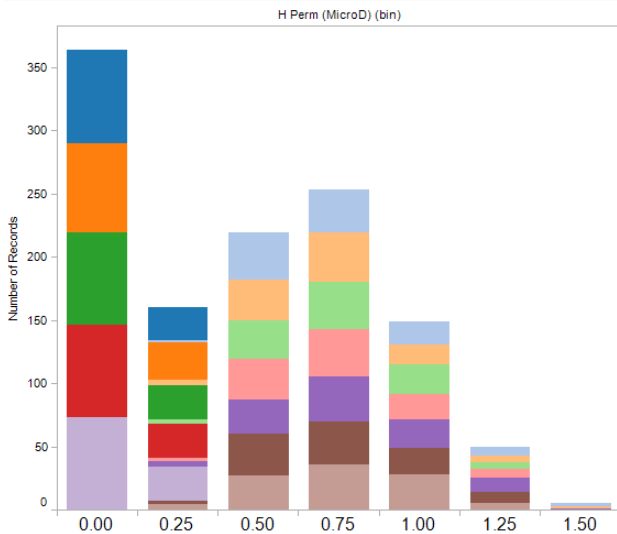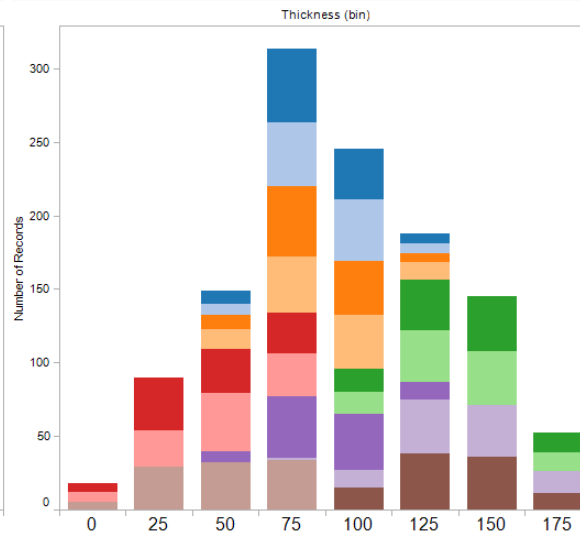
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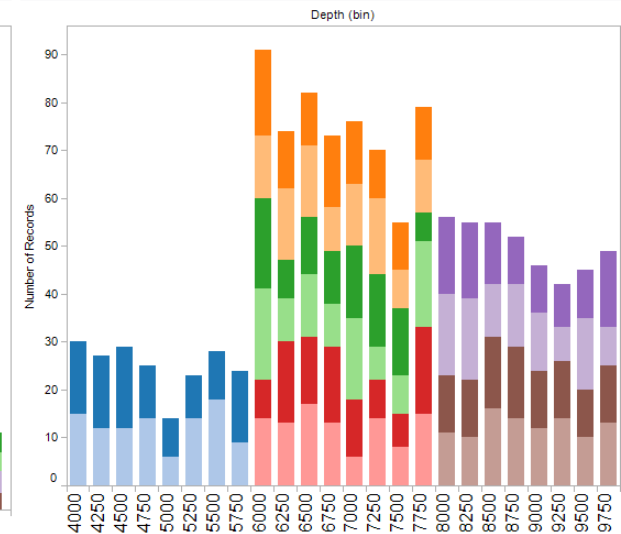
Input Distribution for a single polygon
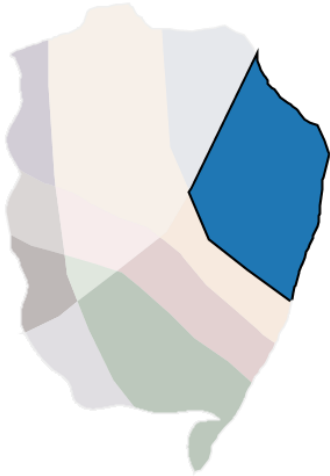
$2 Gas

Subplay Polygons

PVP/EUR - $2

12 Polygons * 100 Trials = 1200 Well EURs and PVPs

← → Geologic Failures

Commercial Failures

PVP MUSD

Well EUR GCF

Rates - $2

12 Polygons * 100 Trials = 1200 "Type" Curves

Gas Rate MSCFD

Time Years

Well EUR - $2

Well EUR GCF (bin)

Number of Records

PVP - $2

PVP MUSD (bin)

Number of Records

Well Spacing - $2

Drainage_Area_Acres

Well spacing optimized to maximize Profit/Mile

-Geology
-Gas Price
-Well Cost

Number of Records

Recovery Factor - $2

Recovery_Factor (bin)

Recovery Factor Dependent on Geology and Spacing
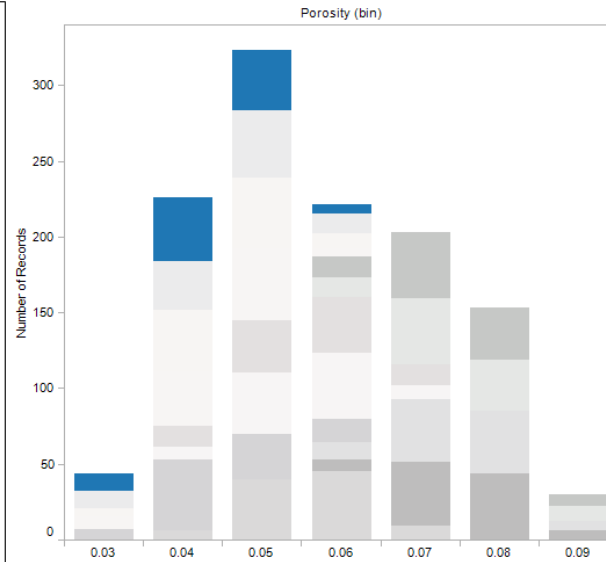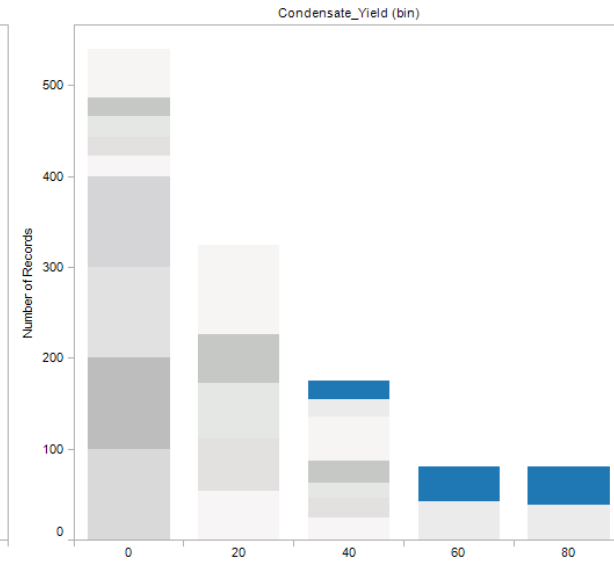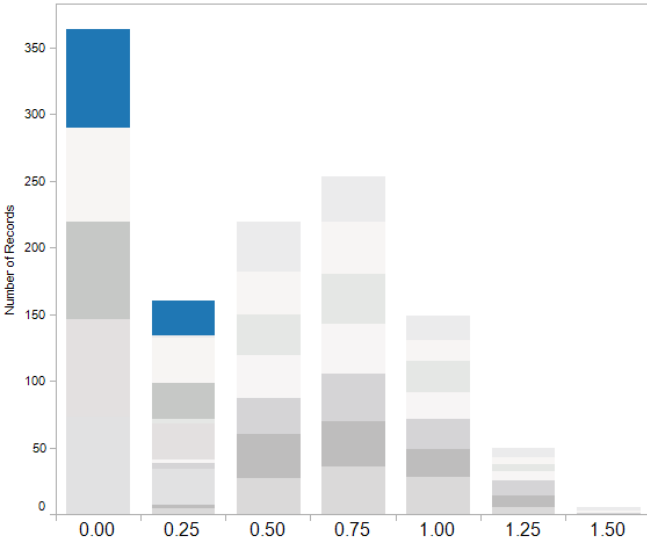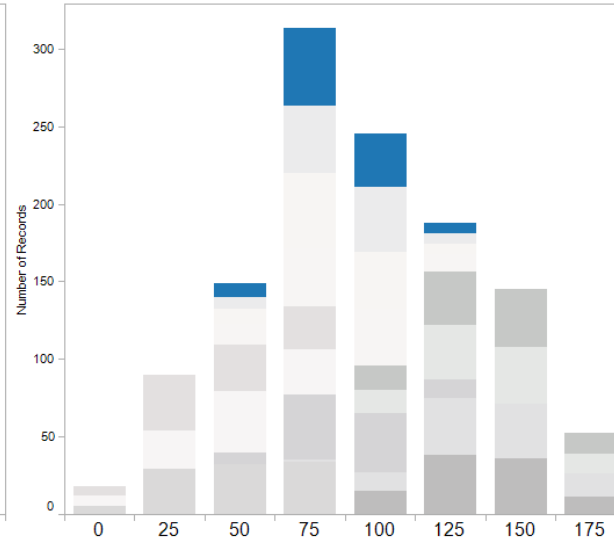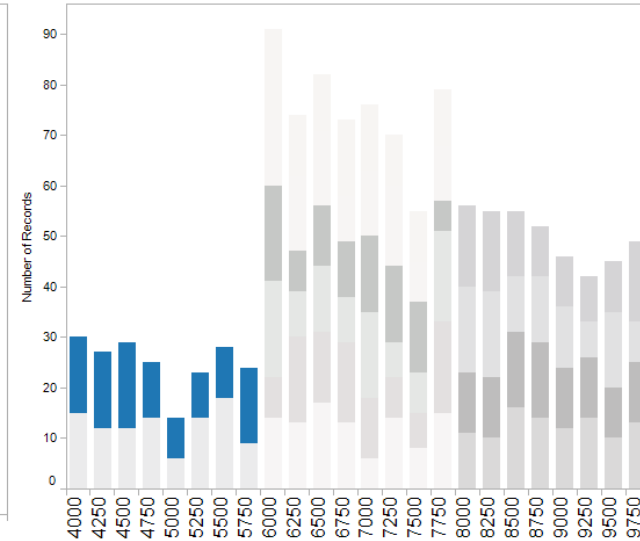
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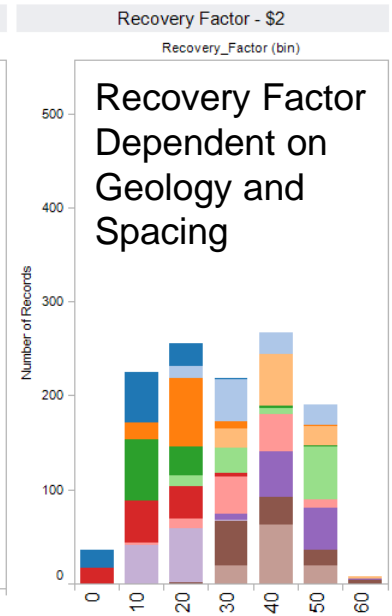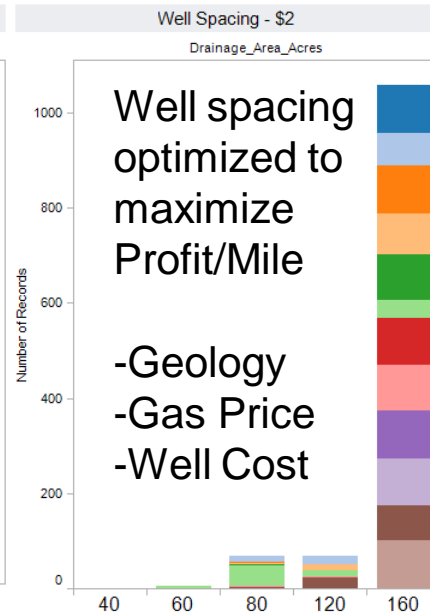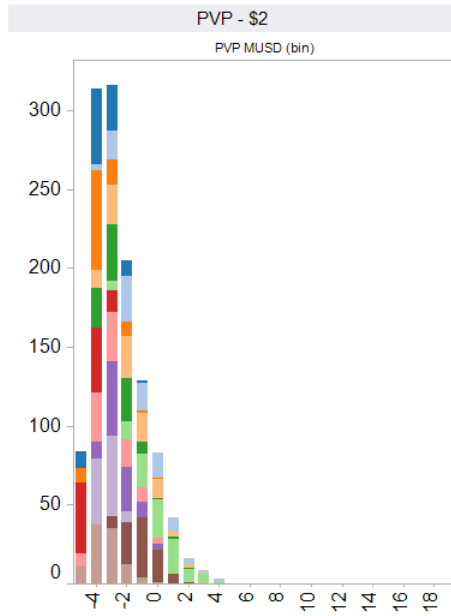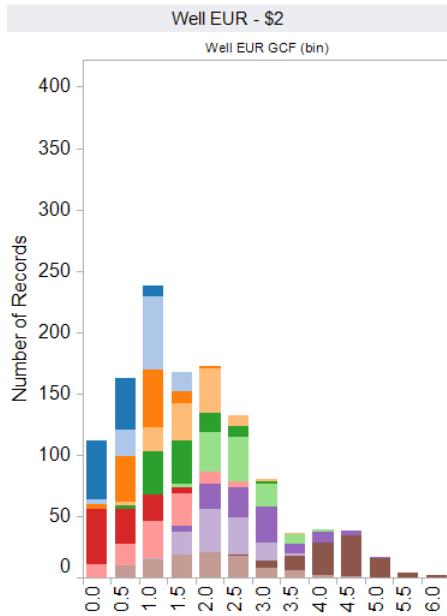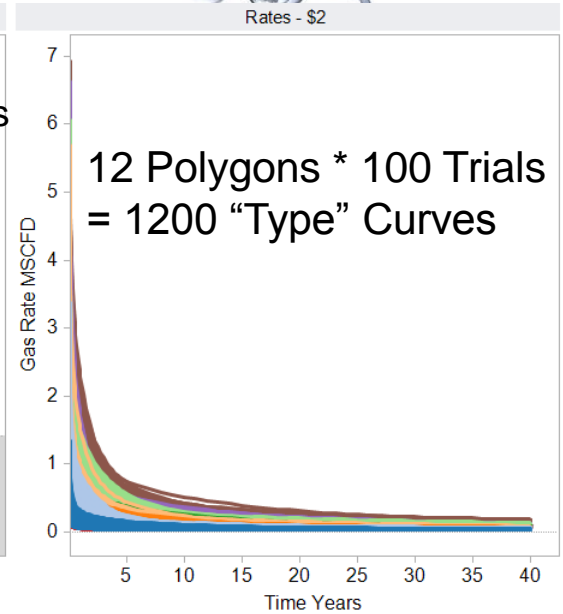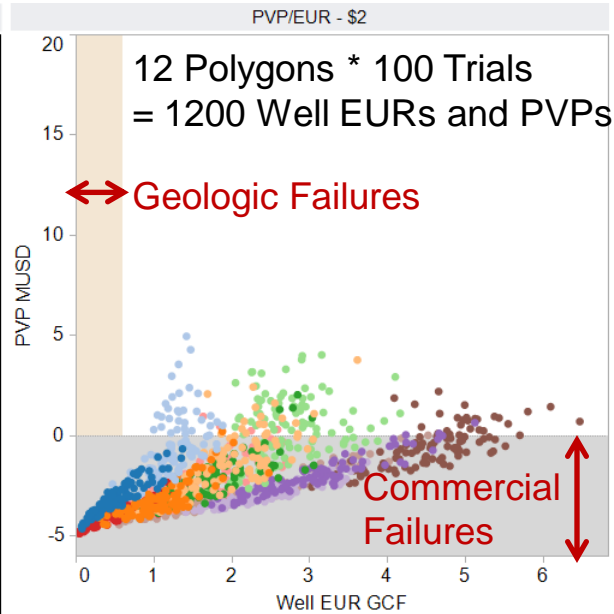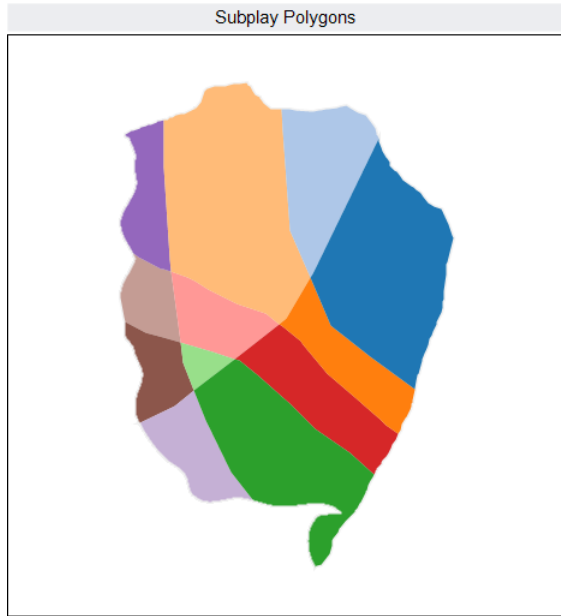
$4 Gas
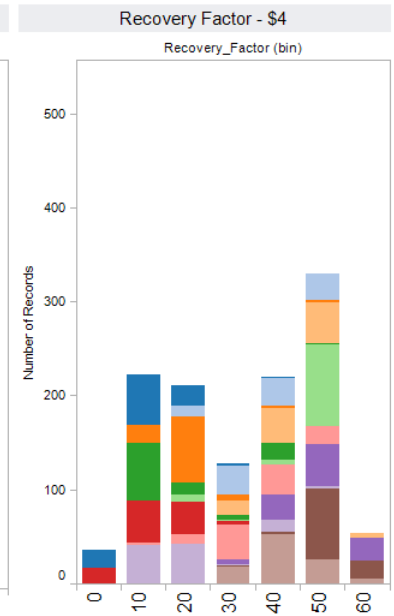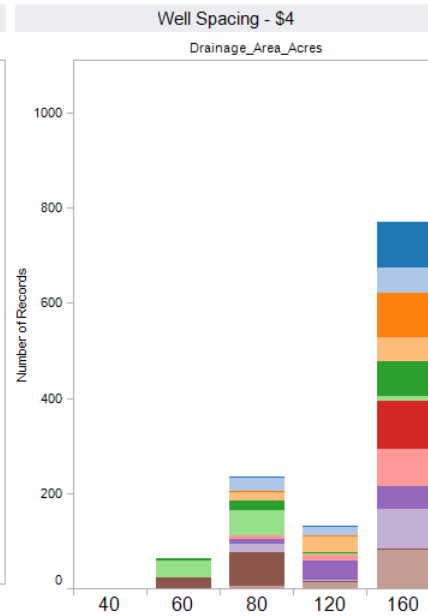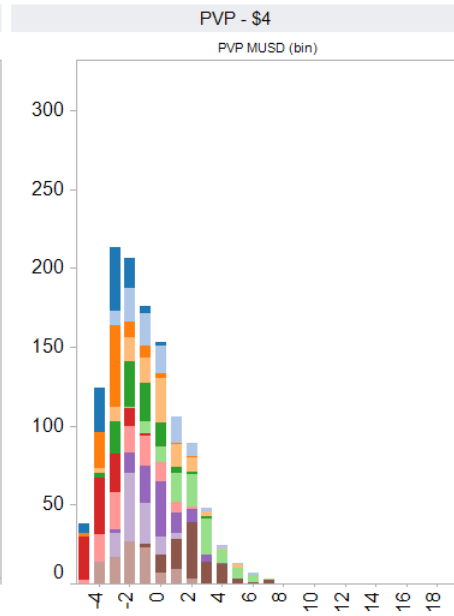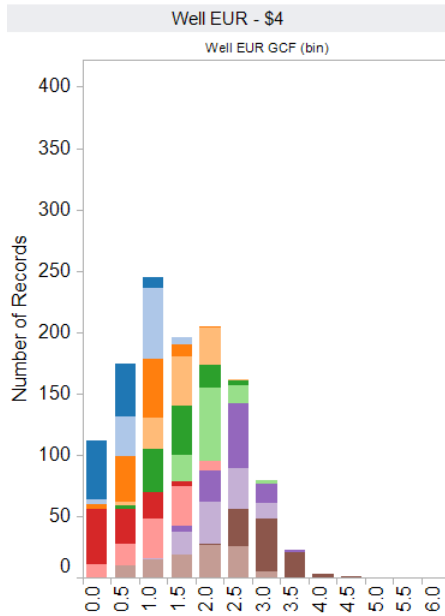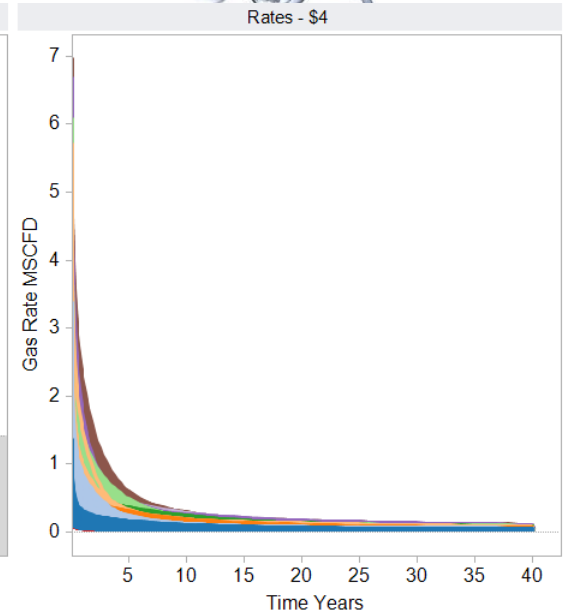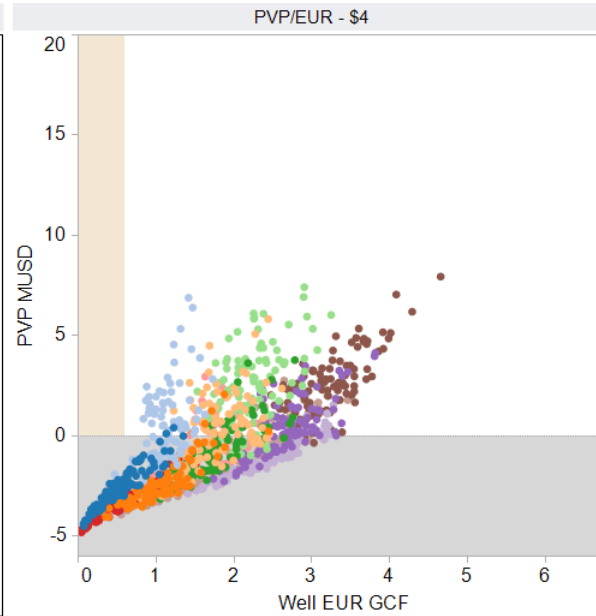
$10 Gas
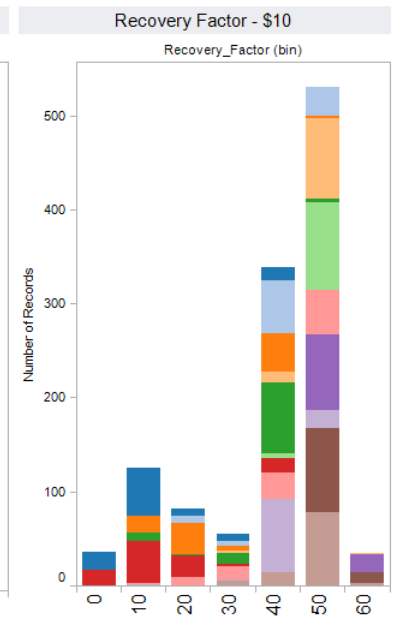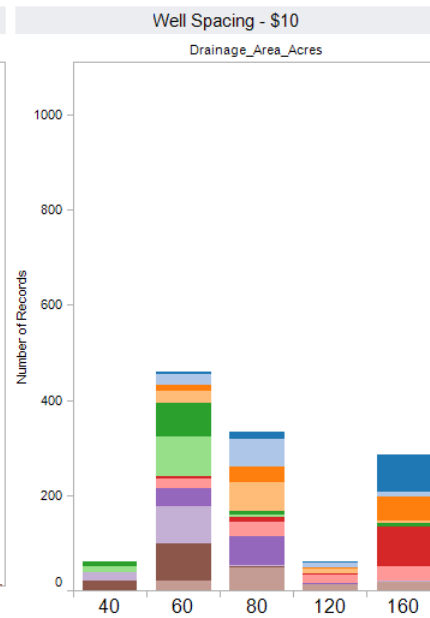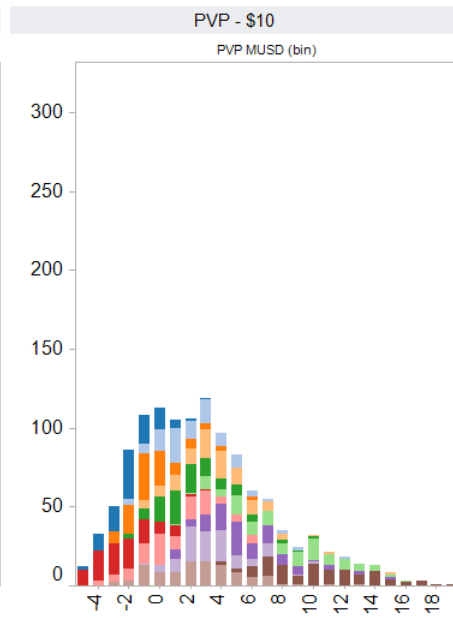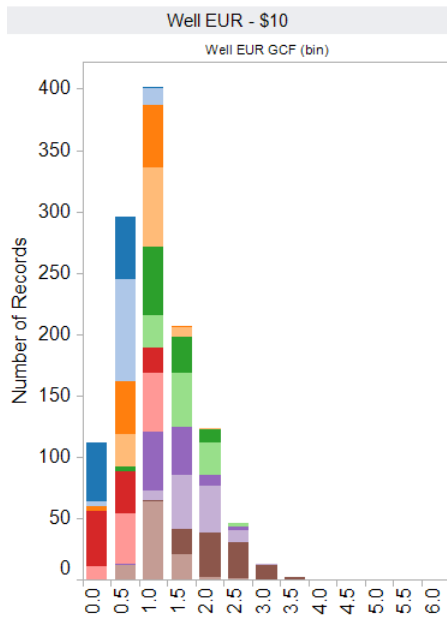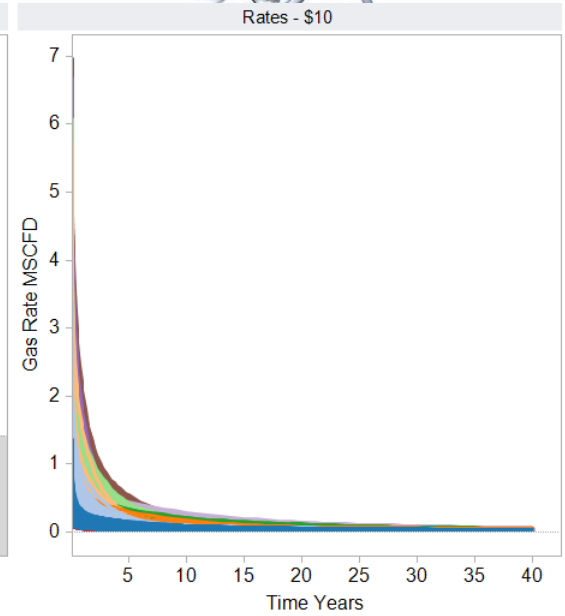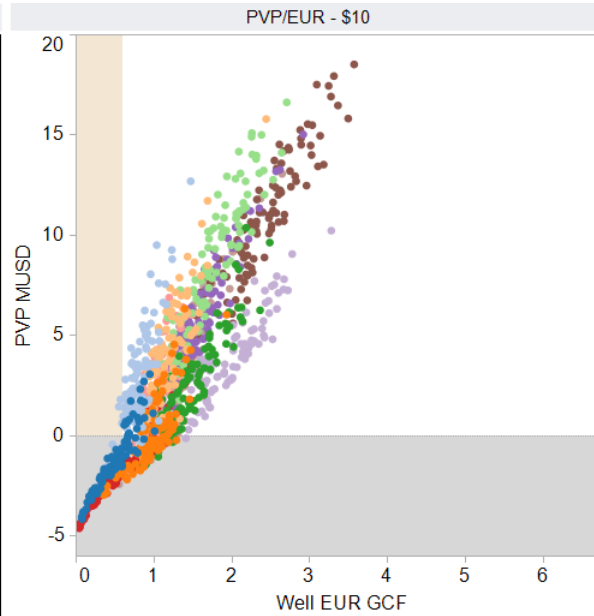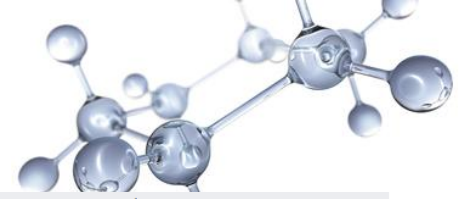
$2 Gas

Subplay Polygons

Geological Volumes - $2
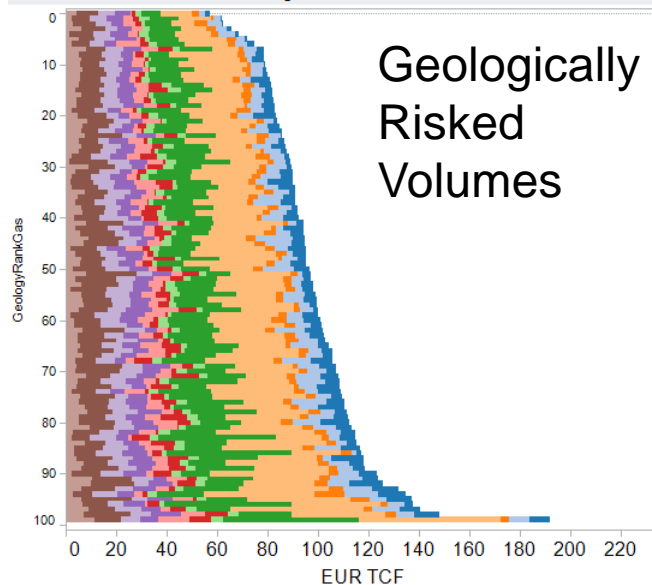
Geologically Risked Volumes

Recovery Factor Polygon - $2

Recovery Factor Commercial - $2
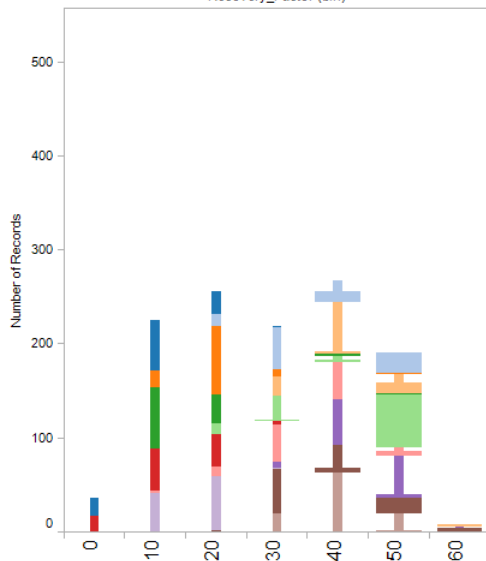
Commercial Volumes - $2

Commercially Risked Volumes PVP > 0
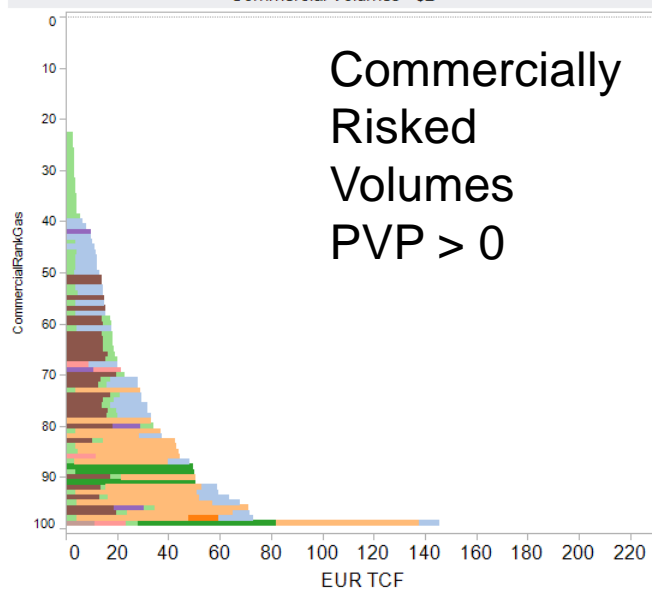
Commercial Success Polygon - $2

Probability of Commercial Success

High

Low
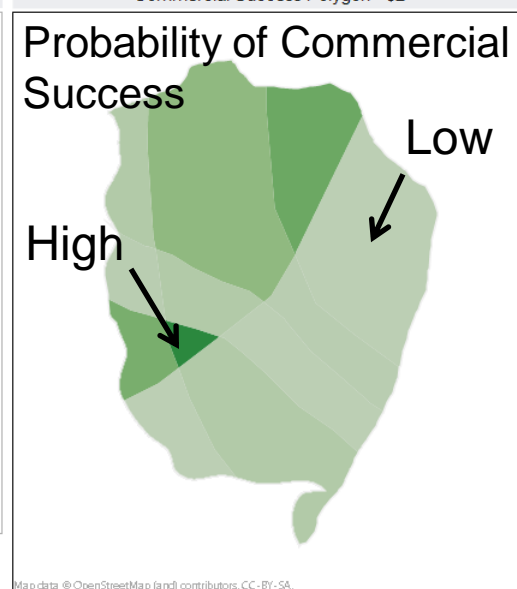
$4 Gas

Subplay Polygons

Geological Volumes - $4

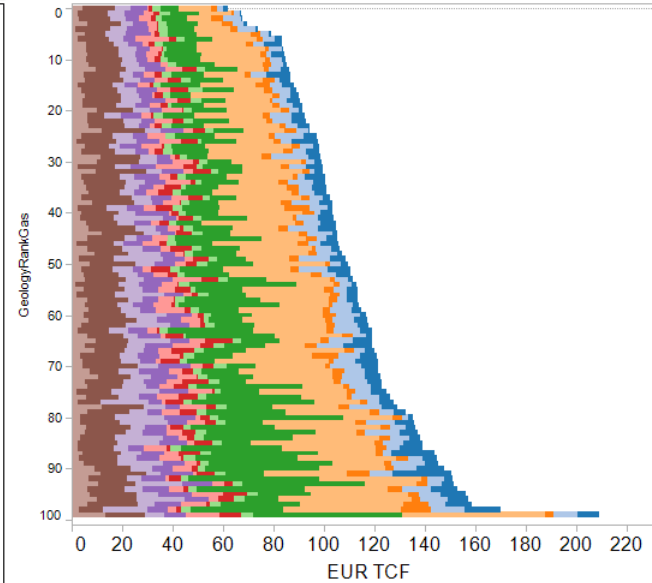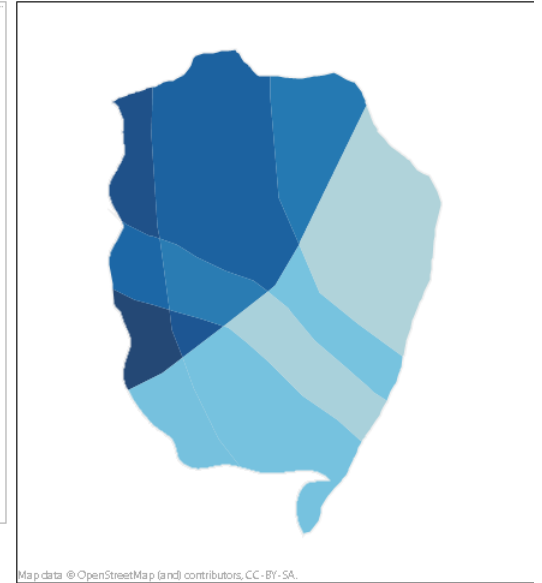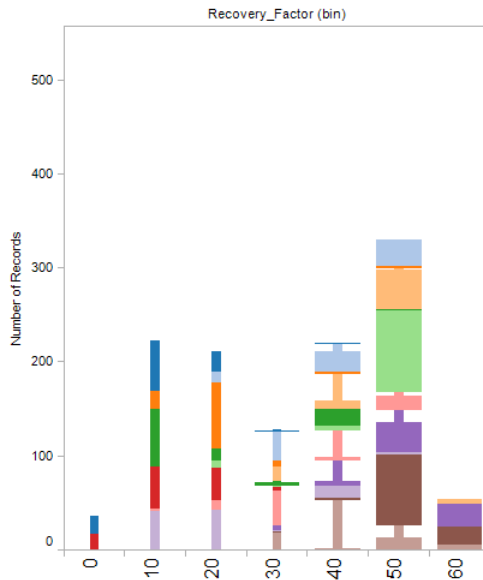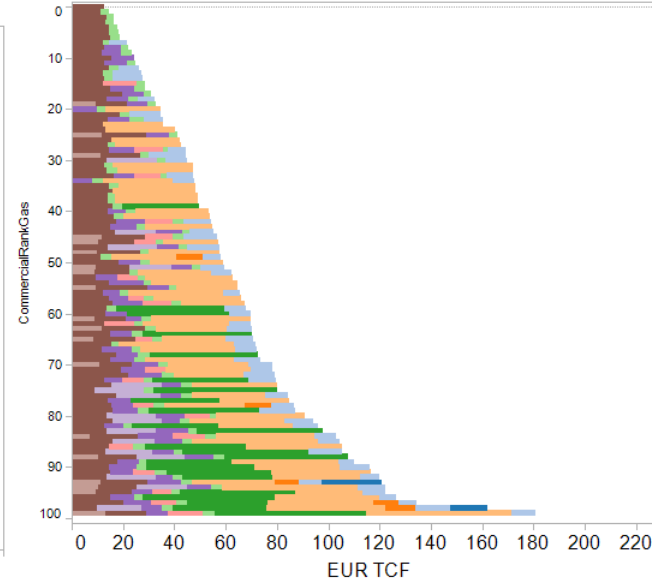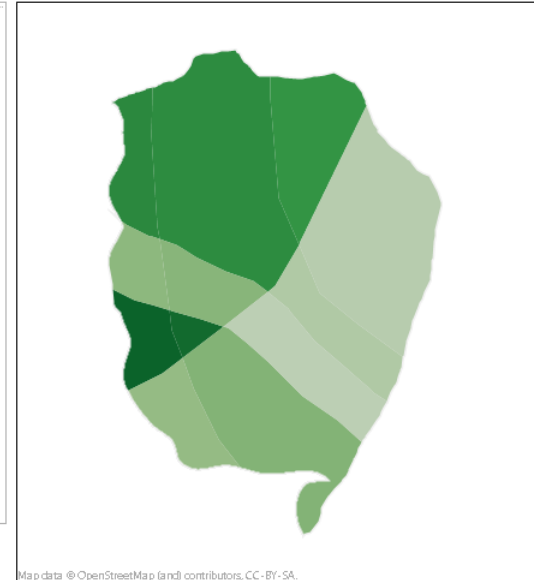Recovery Factor Polygon - $4

Recovery Factor Commercial - $4

Commercial Volumes - $4

Commercial Success Polygon - $4
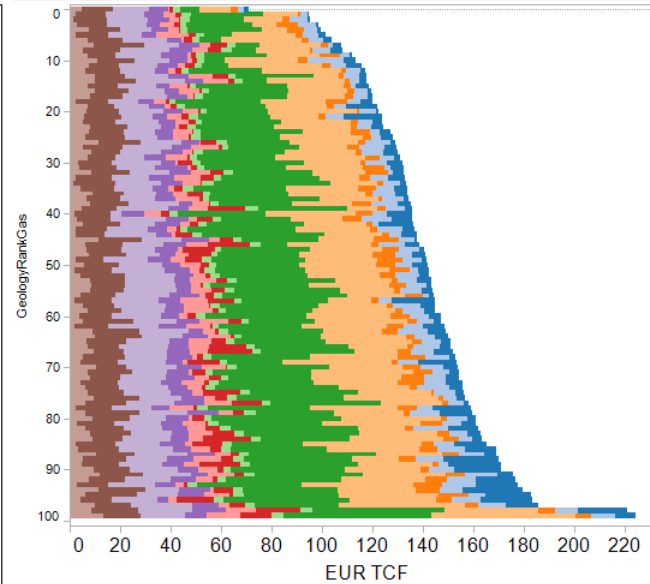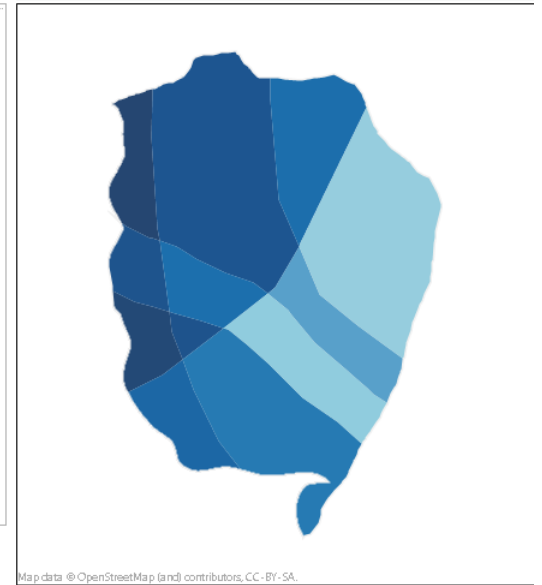
$10 Gas

Subplay Polygons
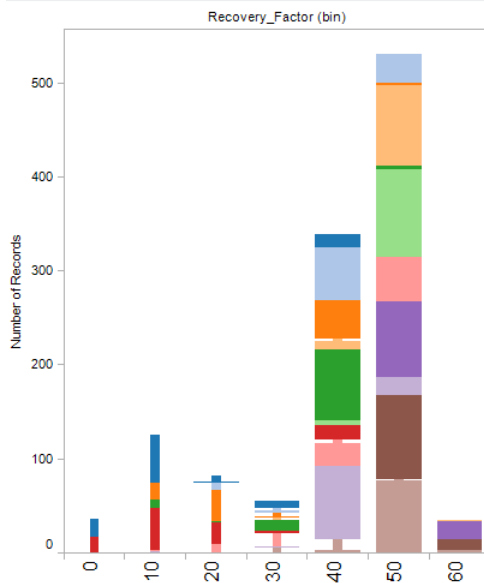

Geological Volumes - $10
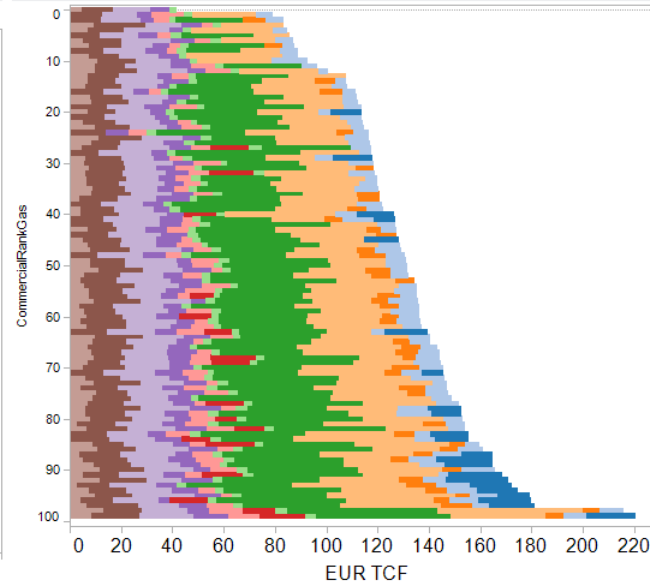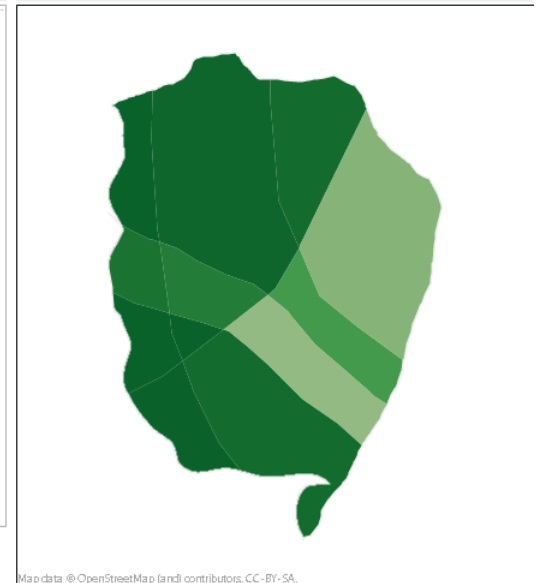

Recovery Factor Polygon - $10

Recovery Factor Commercial - $10

Commercial Volumes - $10

Commercial Success Polygon - $10
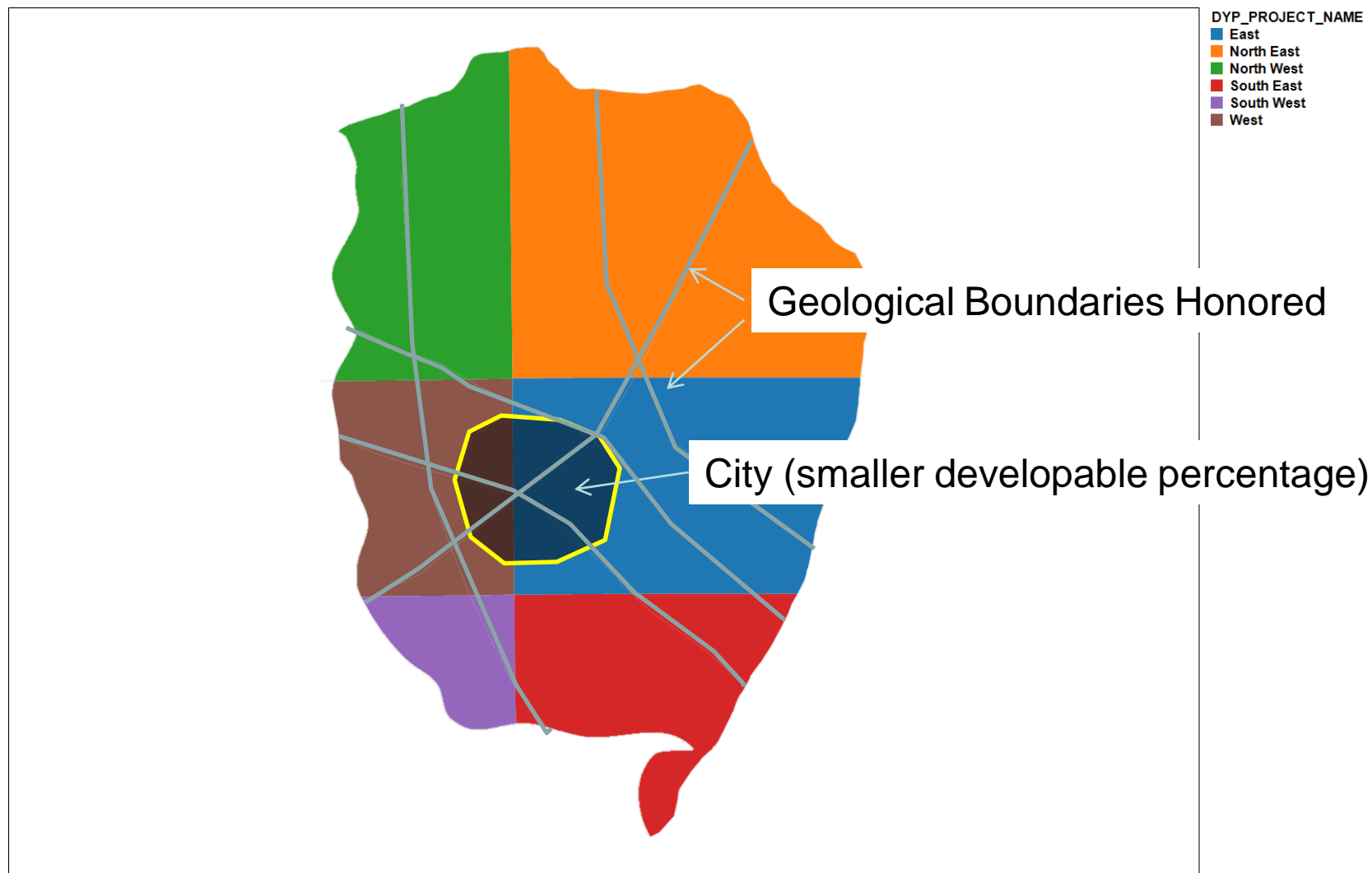
Defining a project

- **Project Definition**
  - **Drilling Method**
    - **Proportional**
    - **Best First**
  - **Start Time**
  - **Project Life**
  - **Fraction Developable**
  - **Plateau Rate**
  - **Maximum Project Cash Impairment**
  - **Maximum Negative Cash Flow (Annual)**

- **Entry**
  - **Working Interest**
  - **Carry**
  - **Bonus**
  - **Royalty**
  - **Walk Away Cost**

- **OPEX**
  - **Per Well**
  - **Per KCF**
  - **Per BBL**
  - **Well Abandonment**
  - **Transport**

- **Project Stages**
  - **Concept (Geological De-risking)**
    - **Duration (Years)**
    - **Number of Wells Drilled Per Year**
    - **Cost Factor**
    - **Time Factor**
  - **Pilot (Commercial De-risking)**
    - **Duration (Years)**
    - **Number of Wells Drilled Per Year**
    - **Cost Factor**
    - **Time Factor**
  - **Ramp Up (Execution Optimization)**
    - **Duration (Years)**
    - **Number of Wells Drilled Per Year**
    - **Cost Factor**
    - **Time Factor**
  - **Exploitation (Harvest)**
    - **Exploitation Number of Wells Drilled Per Year**
    - **Well Days**
    - **Well Cost**

- **Taxes**
  - **Severance**
  - **Ad Valorem**
  - **Income (still working on)**

- **Commodity**
  - **Gas Price**
  - **Oil Price**
  - **NGL Price**

- **CAPEX**
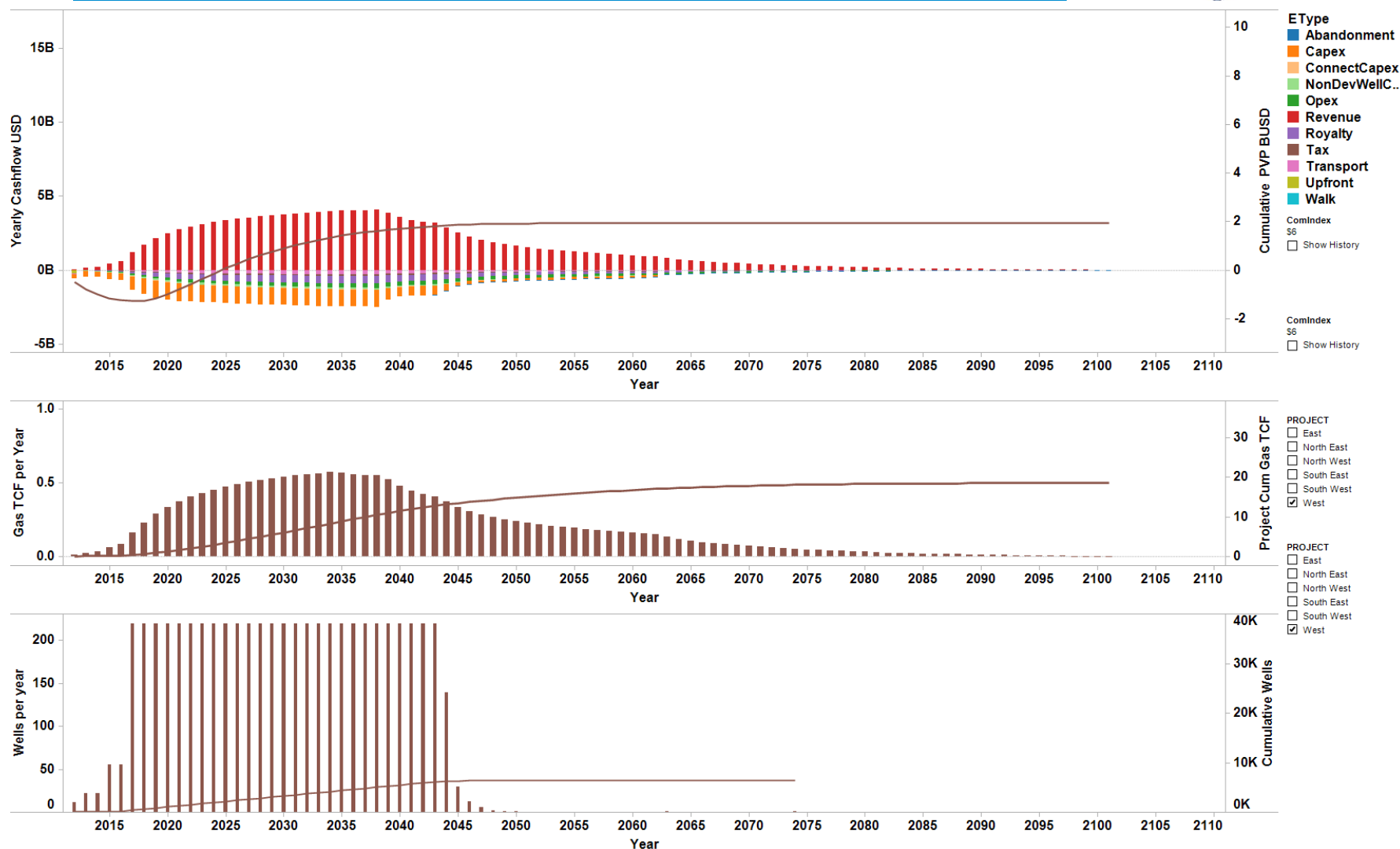 - **Infrastructure**
  - **Non-Drill Wells**

Project Maps

Geological Boundaries Honored

City (smaller developable percentage)

DYP_PROJECT_NAME
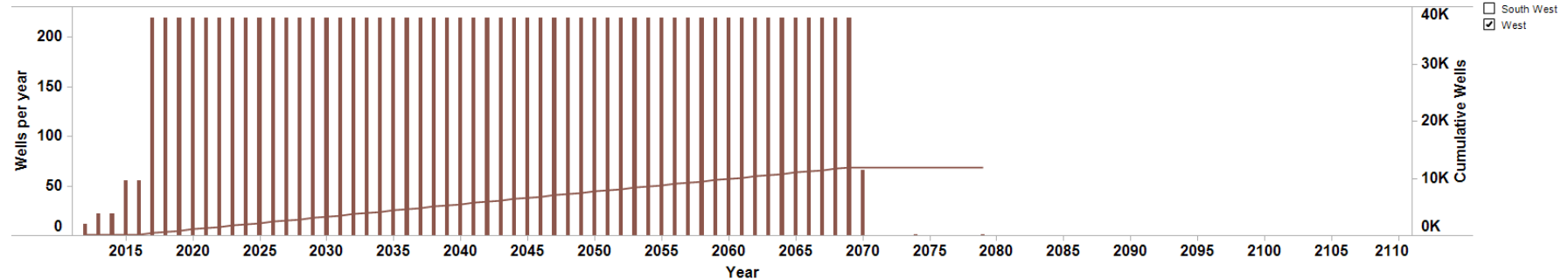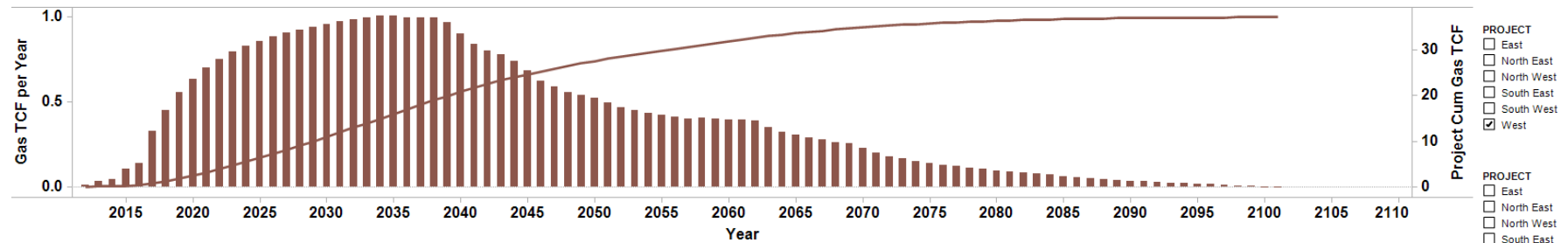- East
- North East
- North West
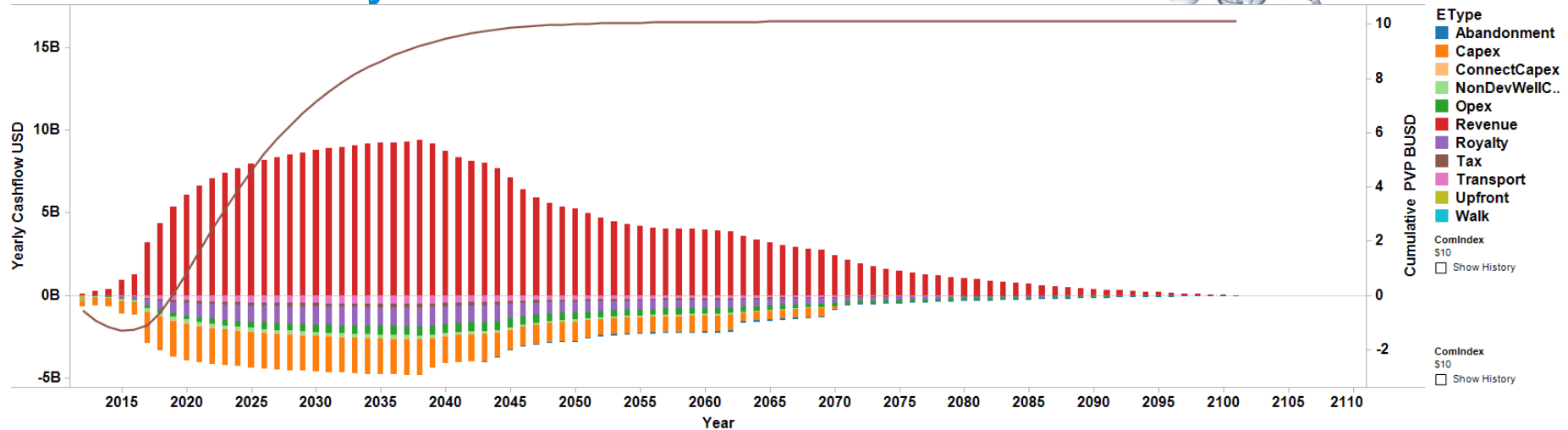- South East
- South West
- West

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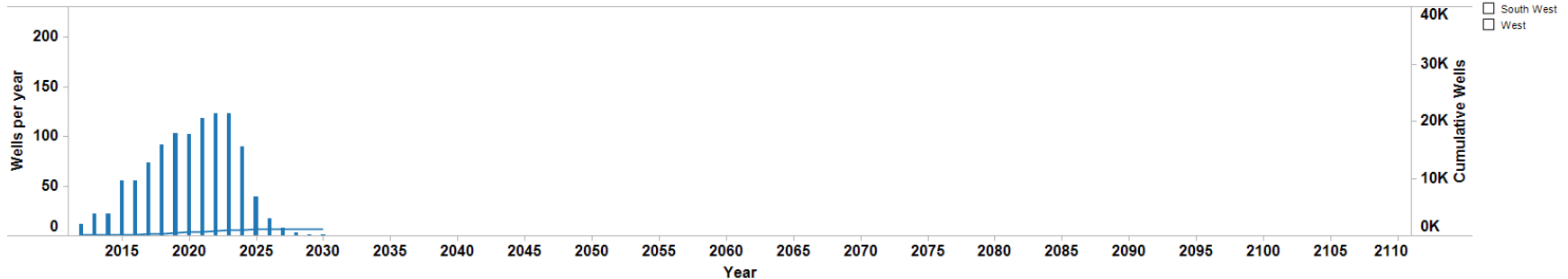# West Project
Geologic Failure Case

West Project $6 Gas
Most Likely Case

West Project $10 Gas
Most Likely Case

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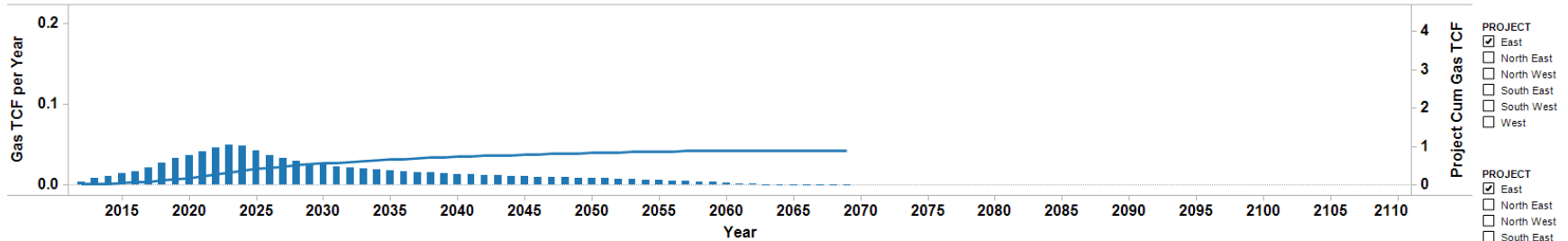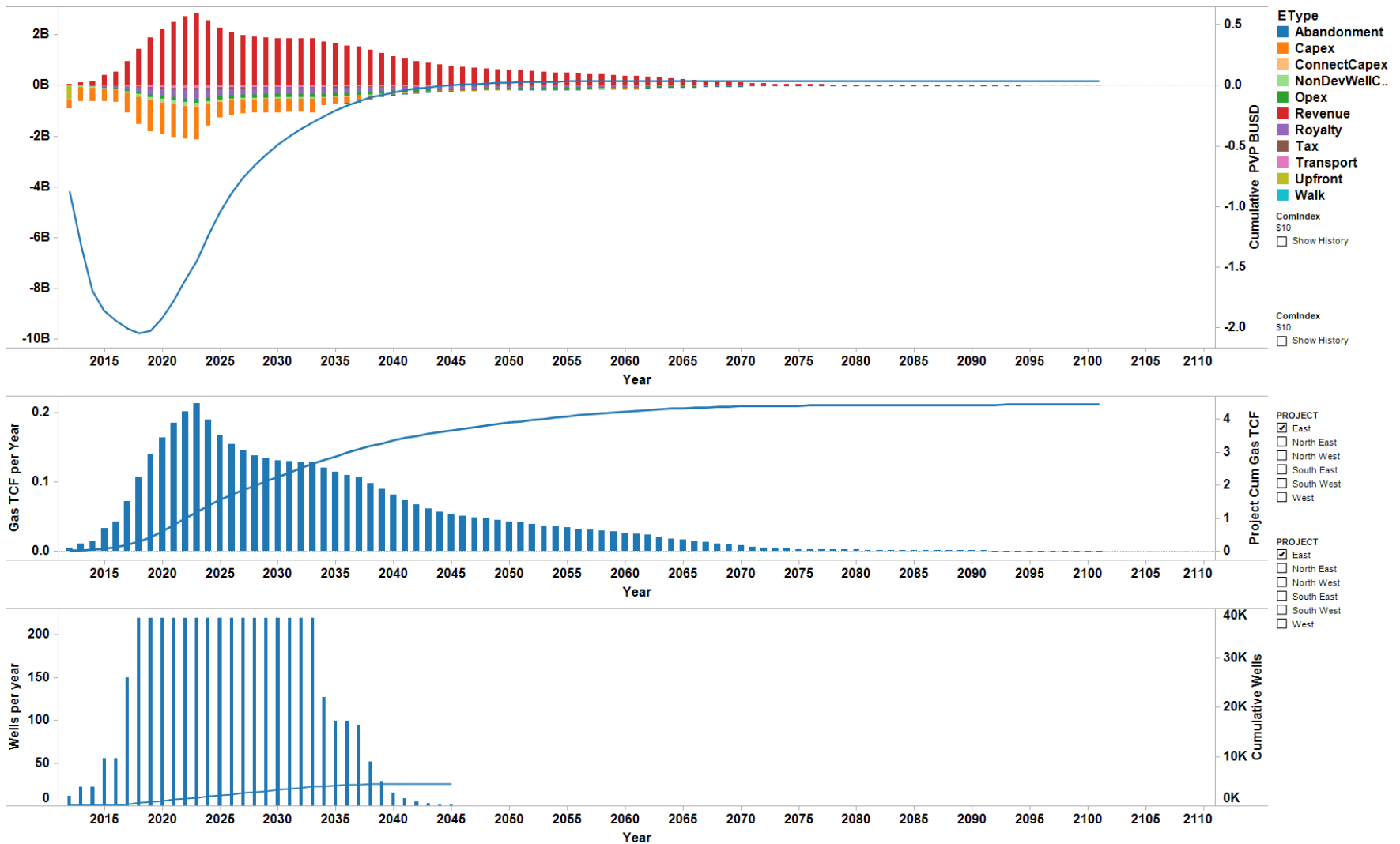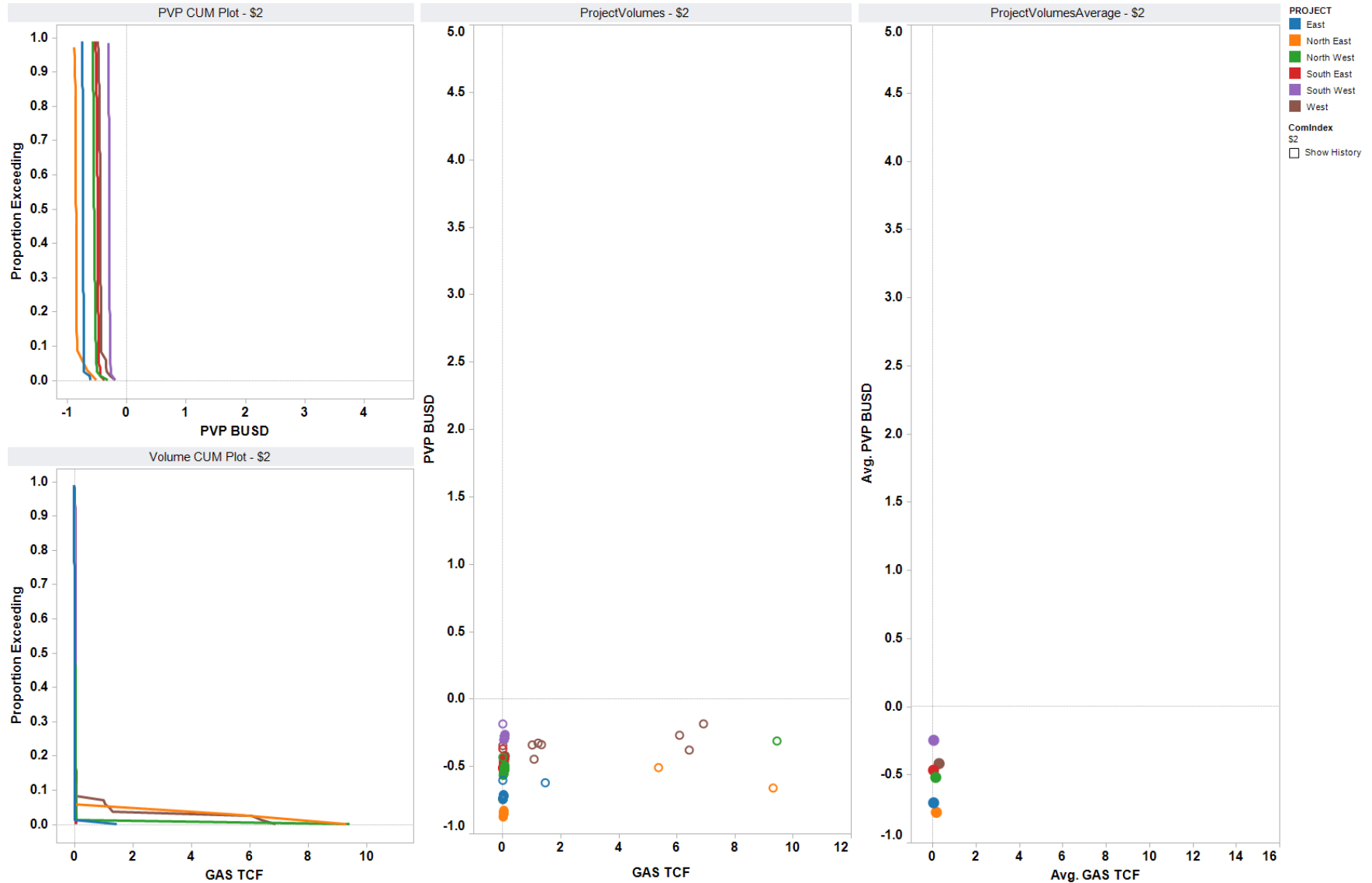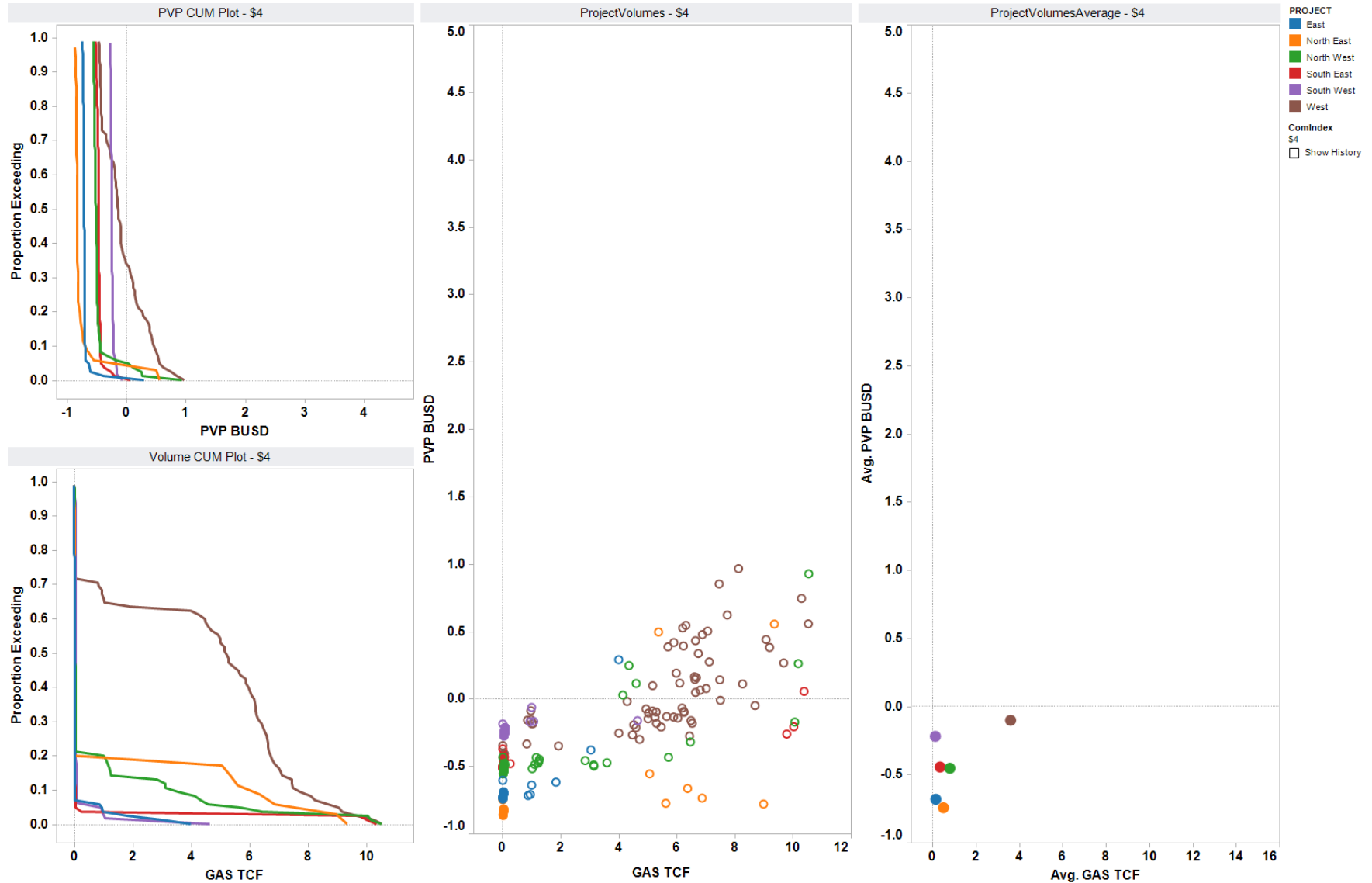# East Project $6 Gas
Most Likely Case
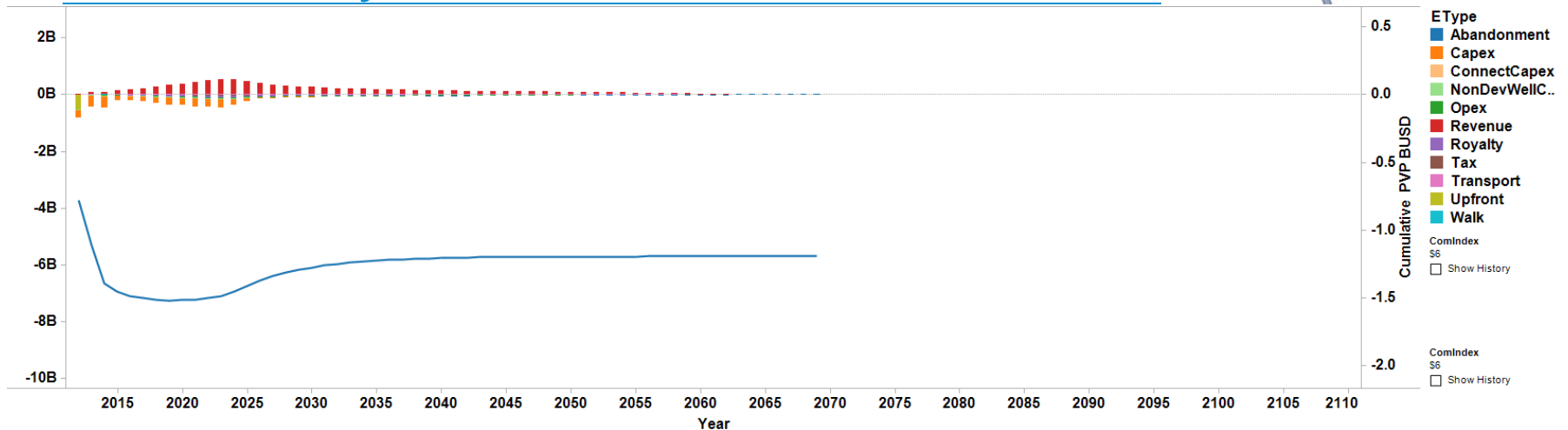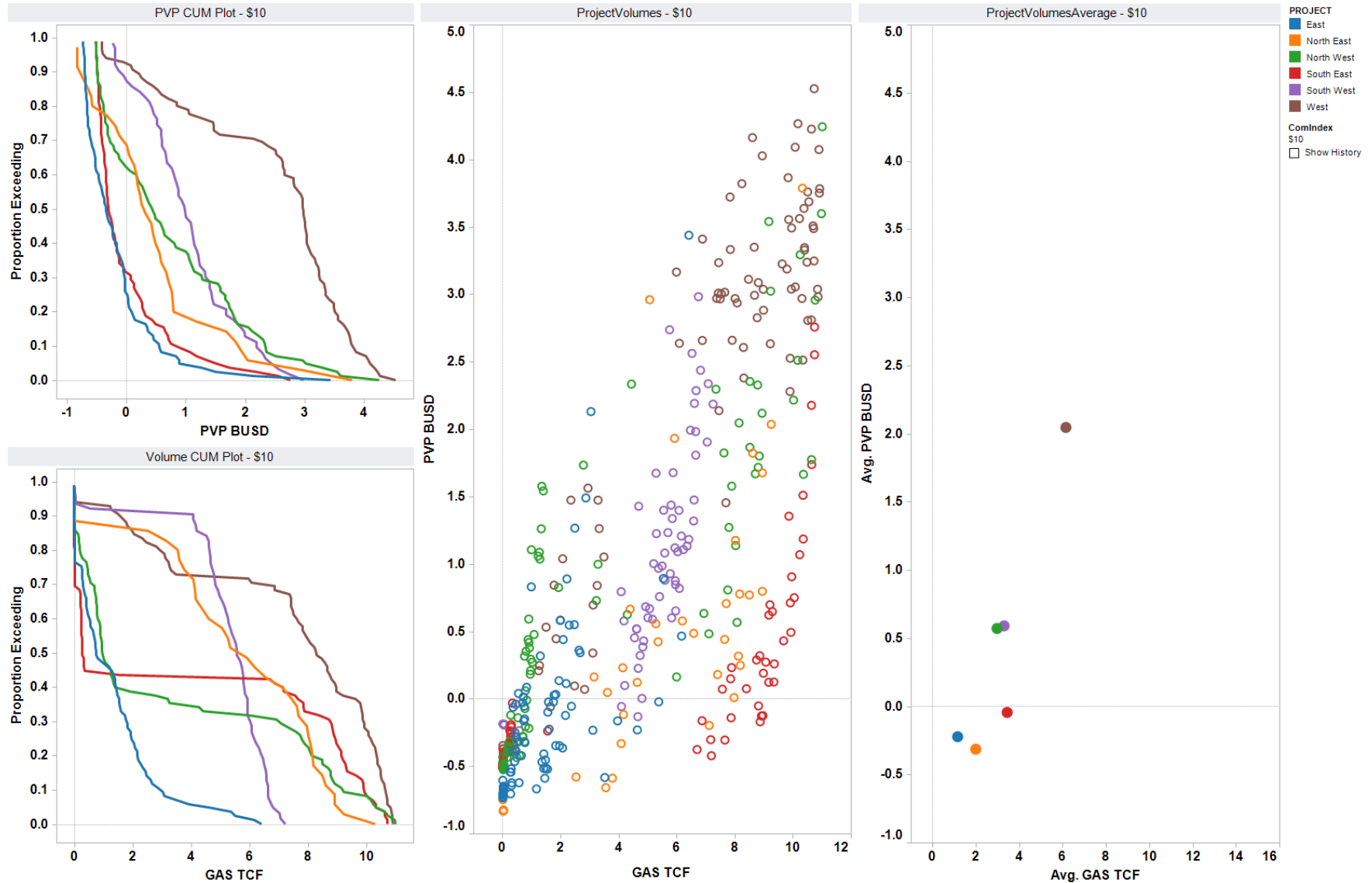
East Project $10 Gas
Most Likely Case

Project Economic Summary $2 Gas

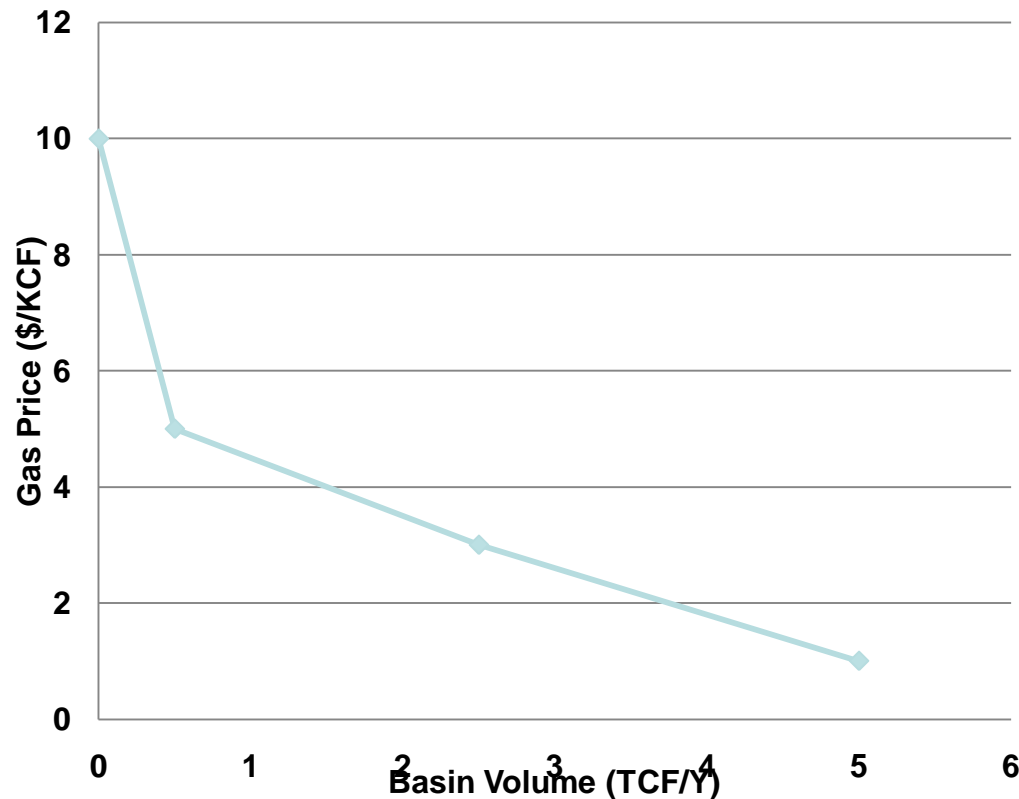# Project Economic Summary $4 Gas
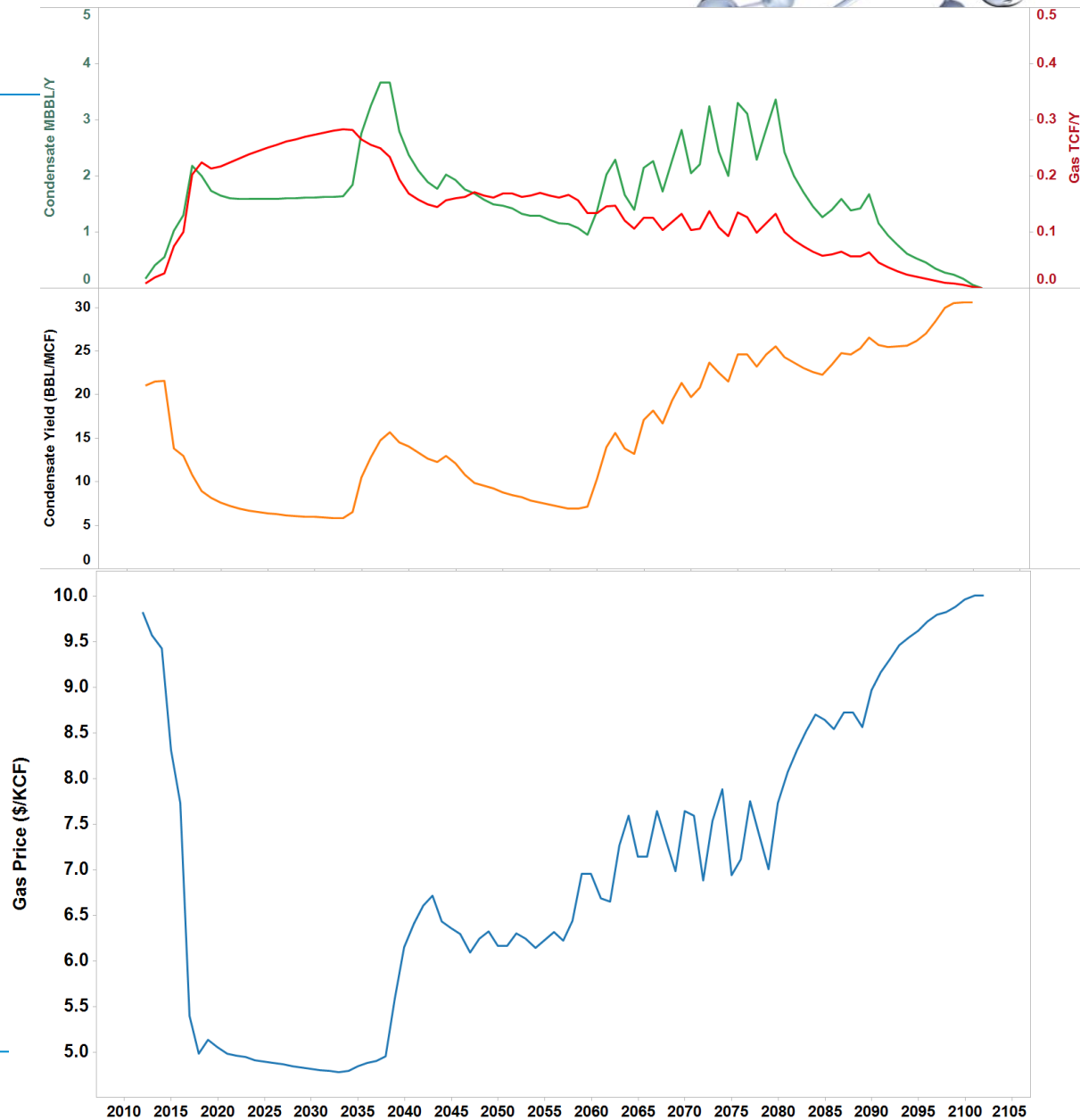
Project Economic Summary $10 Gas

Interactions of Projects

- Modeling the interactions of possible projects in the play with the local markets
- 6 projects in the play
- Condensate price is $80/BBL
- Gas price is controlled by the following demand curve (does not vary with time)

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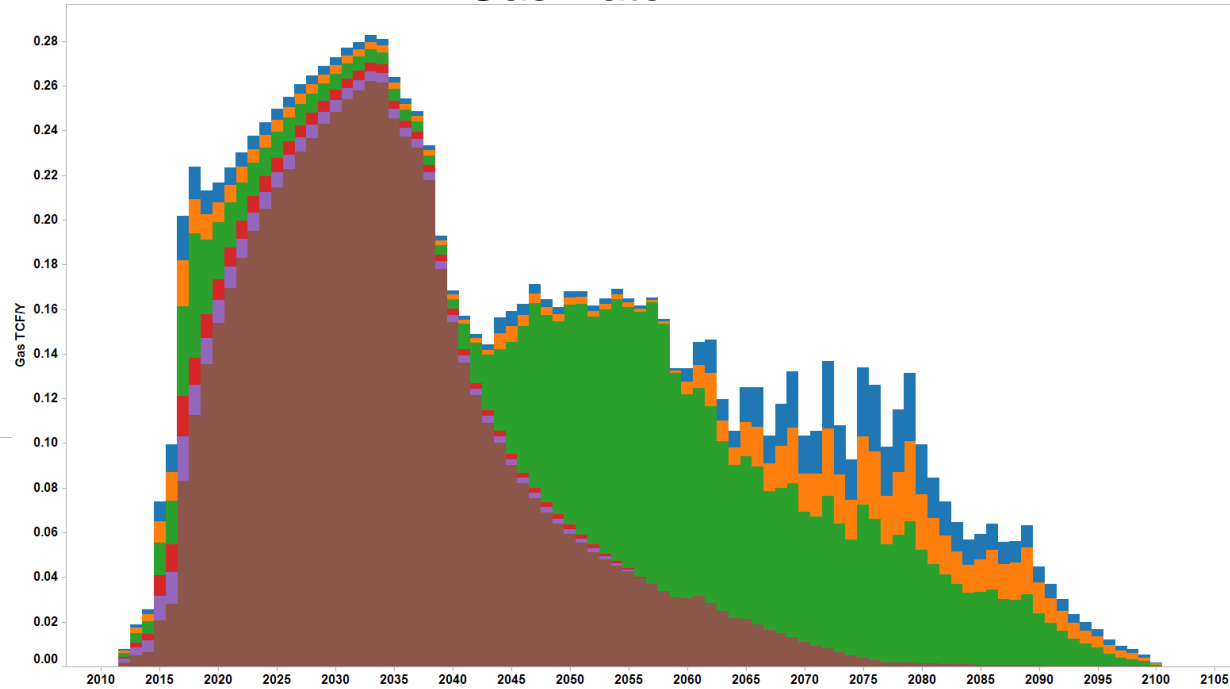
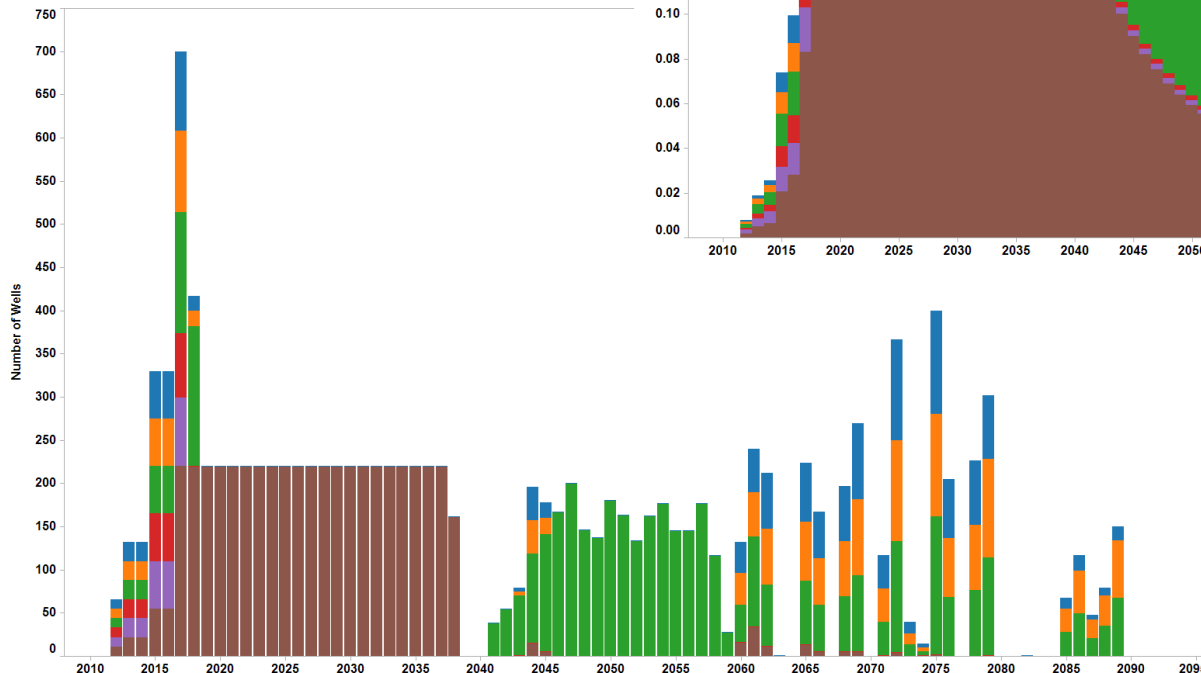# Price/Volume History

Number of Wells and Rates

The West project (brown), has better geology and similar commercial terms, meets market demand and pushes exploitation phase of other projects into the future
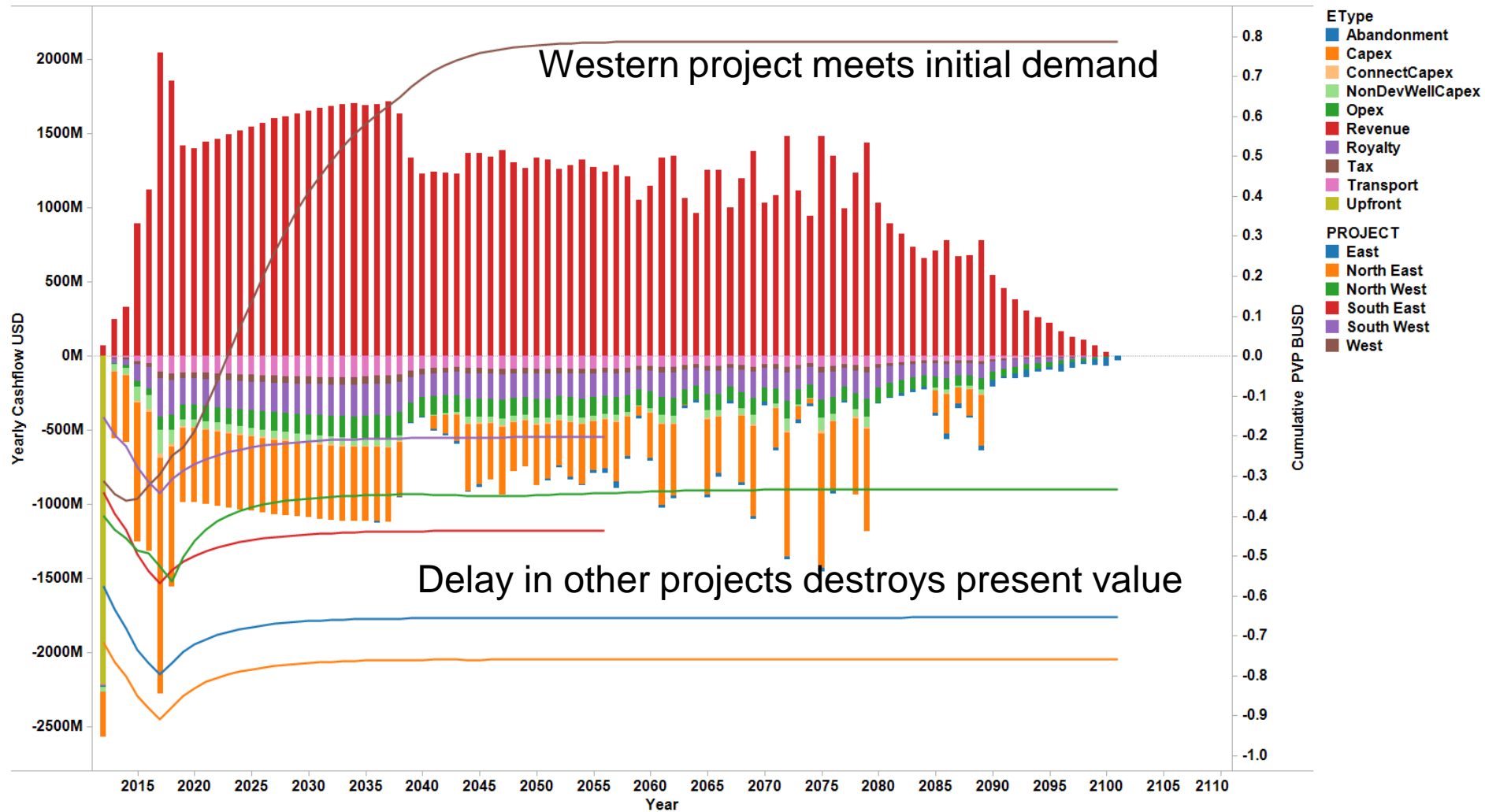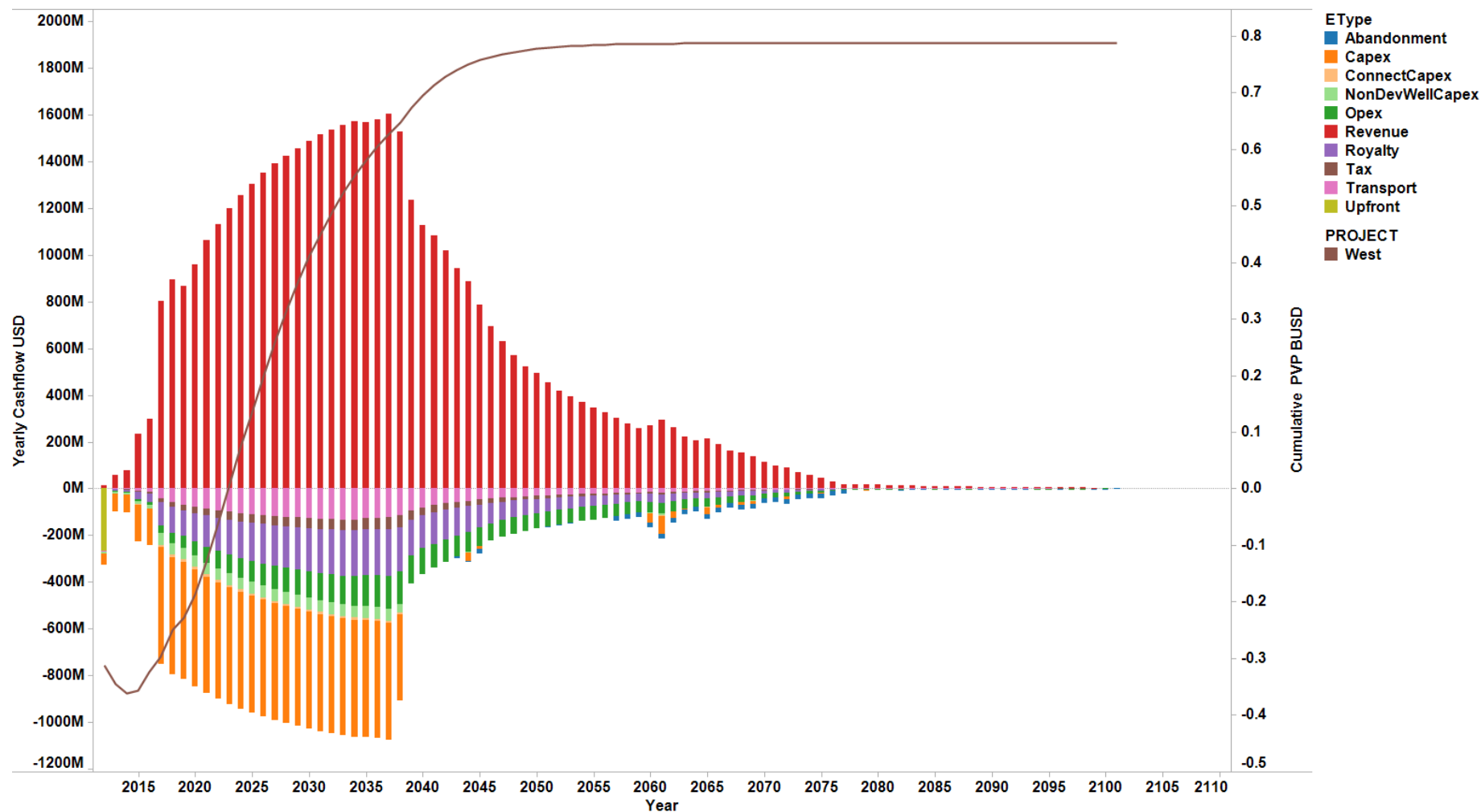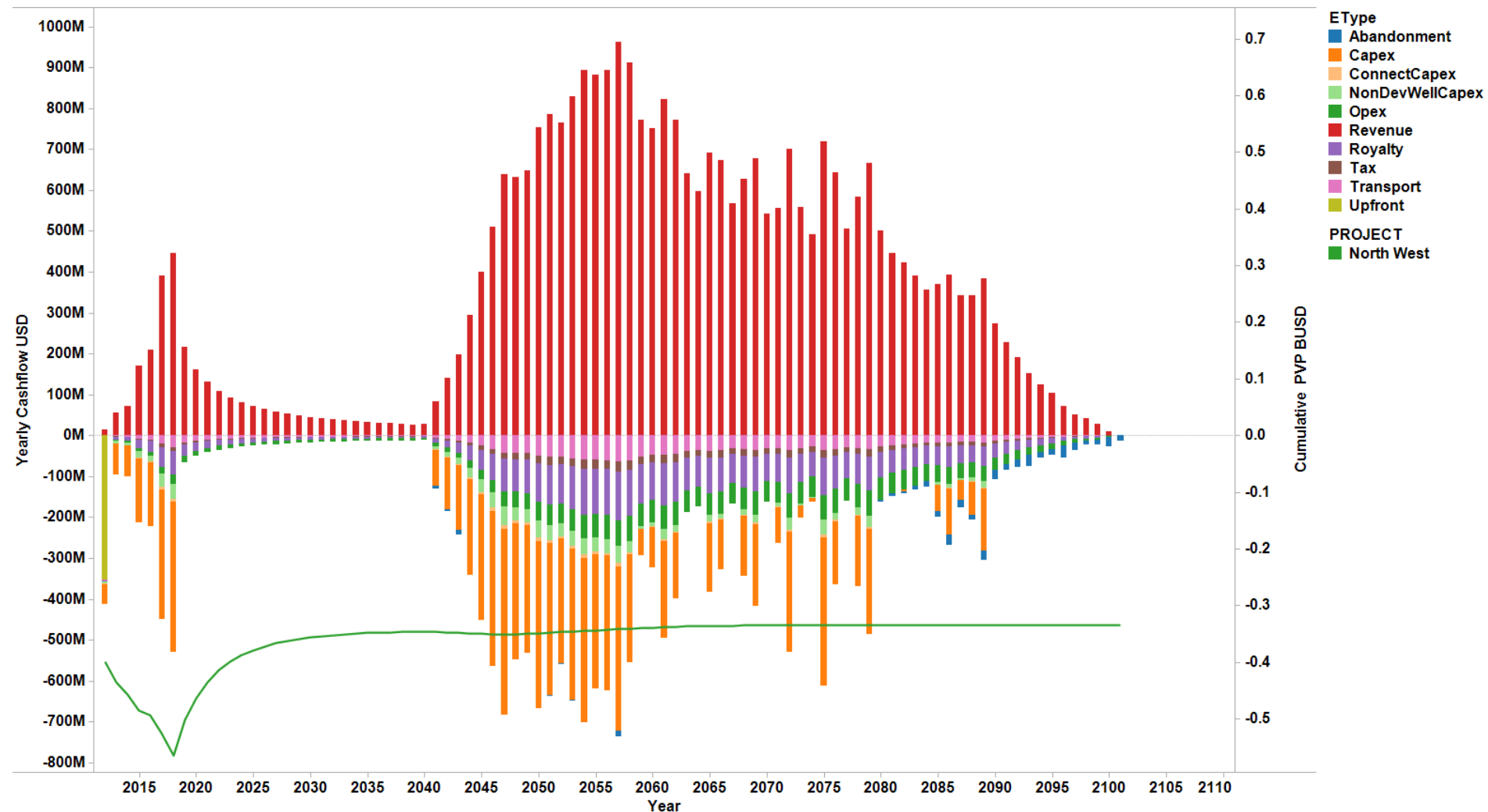
Gas Rate

Number of Wells Drilled

All Projects

Western project meets initial demand

Delay in other projects destroys present value

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Individual Project – West

Individual Project – Northwest

Conclusions

- "Conventional" understanding of risk and uncertainty apply to unconventional resources, but unconventional resources challenge the definition of technically vs. commercially recoverable volumes

- It is critical to integrate geological, engineering, and commercial factors in the evaluation of unconventional resource opportunities

- Unconventional plays are continuously varying and the spatial variation in the quality of the play must be accounted for in the evaluation of opportunity

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